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ECONOMIC EFFICIENCY IN THE MANAGEMENT OF DCS SERVICES

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September 1979

Prepared for

Defense Communications Agency

IDA

INSTITUTE FOR DEFENSE ANALYSES
PROGRAM ANALYSIS DIVISION

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This study analyzes the impact of certain DCS policies and practices on the economic efficiency of communications services. It finds that: (1) present methods of offering and pricing subscriber services create inappropriate incentives for user choices; (2) exclusion of depreciation and certain other expenses from subscriber charges seriously distorts the relative prices of alternative services; and (3) assignment of responsibility for procurement funding affects both the choice and the cost of DCS services.

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Contract DAHC 15 73 C 0200
Task 652-4

PREFACE

This study was prepared in response to Task Order 652-4 under Contract DAHC 15 73 C 0200 with the Defense Communications Agency (DCA). Whereas the previous IDA studies for DCA (i.e., S-487, S-504, and S-506) dealt with pricing issues specific to AUTODIN or AUTOVON, the present study takes a more comprehensive view. Efficiency and pricing issues for the Defense Communications System (DCS) as a whole are analyzed, with special emphasis on incentives for efficient user choices among DCS systems.

The authors are grateful for the time and assistance provided by DCA staff members, particularly John R. Casteel (COTR), R.F. Gutt, R.P. Brownfield, M. Masterson, and D. Sloane. We also appreciate the support of all those at IDA who aided in the production of this study.

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EXECUTIVE SUMMARY

Our objective in this study has been to examine the overall operations of the DCS, to determine whether or not economic inefficiencies exist and to evaluate potential means of correcting them. We have analyzed three problem areas, with emphasis on the first: (1) the definition, adequacy and pricing of services, particularly as applied to common-user networks and dedicated circuits; (2) the allocation of full costs in the pricing of services; and (3) the control of and accounting for capital expenditures and procurement. On the basis of our analysis we have made a number of recommendations and observations concerning the operations of the DCS.

In conducting this study, we have viewed economic efficiency as requiring the best use of available resources to accomplish particular mission objectives. For the DCS, the primary objective is to provide for wartime communications requirements, and a secondary objective is to utilize wartime contingency facilities to meet peacetime needs. Decisions affecting either objective influence the allocation of scarce resources, and hence economic efficiency is a relevant consideration for both types of decision.

In evaluating communications efficiency, however, it is important to recognize that systems which are efficient in terms of wartime objectives may appear inefficient in light of peacetime requirements. While incentives should be structured to promote efficient communications choices for both wartime and peacetime requirements, such incentives must not cause wartime objectives to be sacrificed in the name of peacetime efficiency.

From an economic standpoint, there appear to be five major manifestations of inefficiency in the DCS:

- There seems to be excessive reliance on dedicated circuits, at the expense of common-user systems. $632 million of the total estimated $993 million cost of DCS in FY78 was attributable to dedicated circuits.
- Dedicated circuits (even when justified) are not always provided in a manner which minimizes total cost to the government. Satellites, for example, appear to be free to the user but are not always the low-cost transmission medium for particular requirements.
- Given its current size and capacity, there is less than optimal utilization of AUTODIN. Between 38 and 74 percent of capacity is utilized, depending upon which characteristic is considered.
- There is insufficient AUTOVON capacity relative to demand at current prices, leading to congestion, wasted time, and inappropriate use of more expensive substitutes. The backbone grade of service is P14 within CONUS and P43 between CONUS and Europe. Caller-to-caller, the grade of service is often worse than P40 in CONUS.
- In some cases, the provision of services using government-owned equipment is neither optimal nor fully responsive to user needs.

These manifestations of inefficiency, however, are analogous to the symptoms of a disease--they are merely evidence that it exists. Although they attract attention, they are not causal. Only by addressing the causes of inefficiency can management decisions affect these manifestations of inefficiency. The major causes of inefficiency are:

- Subscriber charges are not sensitive to usage and do not reflect the cost of service.
- There is an insufficient variety of services on common-user networks and there are few price alternatives among the services which are offered.
- Services provided by DCS common-user networks are often of low and undependable quality unless the user has a high precedence assigned.

- Budget incentives for DCS subscribers and actual users are often misdirected or non-existent.
- Full costs are not reflected in most subscriber charges and relative prices are distorted.
- Procurement is decentralized with major users individually responsible for the acquisition and funding of components of the DCS.

The first four sources of inefficiency relate to the category of problems we have labeled *definition, adequacy and pricing of services* (Section A). The last two correspond to *full-cost pricing and decentralized funding of procurement* (Sections B and C).

A. DEFINITION, ADEQUACY AND PRICING OF SERVICES

One of the major manifestations of inefficiency is the degree of dependence on dedicated circuits, and much of our analysis of the definition, adequacy and pricing of services involved comparison of dedicated and common-user networks. The three principal areas in which we made comparisons were: (1) costs and pricing; (2) variety of services; and (3) adequacy of service and congestion costs.

In connection with *costs and pricing,* we made a number of observations. For example, point-to-point telephone service could be provided by a common-user network or a dedicated circuit. When no additional access lines (from users to the network) are required, the service can almost invariably be provided at less cost to the government on a common-user system, as long as the circuit is used less than 30 percent of the time (during busy periods). On the other hand, if new access lines are required, the common-user alternative is likely to be the most expensive unless the point-to-point distance is very large. According to our estimates, the distance below which a dedicated circuit is, on average, less costly than using the AUTOVON

backbone is around 800 miles, if the line is used only 10 percent of the time.[1] With heavier usage the breakeven distance increases.

We arrived at two principal conclusions concerning the cost of dedicated circuits compared to the common-user networks, assuming identical kinds of service. First, *it is not possible to generalize about the desirability of one compared to another or, given currently available data, to estimate the degree to which dedicated circuits are at present excessively relied upon.* Each circumstance is different. Callers are situated at different distances from backbone trunks; they have different requirements for additional access line capacity; the amount of backbone trunk required to serve them is different; and their degree of usage is different. All of these things affect the cost of the common-user alternative to a dedicated circuit.

Second, *it is possible, however, to develop procedures for making an accurate comparison between the cost of a dedicated circuit and the cost of its common-user alternative for each individual case.* All of the variables mentioned above that affect the cost of the common-user alternative can be measured, with the exception, at present, of the degree of usage. If information on expected utilization can be obtained, then the cost of providing point-to-point service can be estimated and the least costly method can be identified.

At present, these costs are neither calculated nor used in selecting services and the means of providing them; but in order to make efficient choices, a subscriber must have knowledge of the costs of alternatives and some incentive to choose the least costly. This can be accomplished only if the price he pays reflects the costs of the service he buys. If service on a

[1] This calculation assumes two access lines 86 miles long (the average for AUTOVON) are required and the backbone trunk distance is equal to the point-to-point distance for a dedicated circuit. (See pp. 46-52 of text.)

common-user network is less costly (to the government), his subscriber charge should be less than the price he would pay for a dedicated circuit.

Currently, the price a subscriber pays for access to a common-user network is only accidentally related to the cost of providing the service that he actually uses. If price is considered to be one of the characteristics that defines a particular service, the problem can be examined under the more general heading of a *lack of variety of services on the common-user networks*. With dedicated networks, a subscriber can define his own community of interest and pay just the costs of communicating with that community. On the common-user network, he either has access to every subscriber (e.g., AUTODIN)[1] or all subscribers within a broad geographical area (e.g., AUTOVON), and he pays a large fixed fee. If he needs less service or different service, he has no options. His main alternative is to order dedicated circuits. For example, a Flash AUTOVON requirement connecting five communications points would incur $7,300 per month in subscriber charges and access line costs. If the average distance between these calling points were less than 1100 miles, it would be less costly (to the subscriber) to connect them with dedicated circuits.

Throughout this discussion we have been ignoring the fact that services generally available on common-user networks differ from those provided by dedicated circuits, not only with respect to price and community of interest but also in terms of *quality*. Unless an AUTOVON subscriber has high precedence, for example, he may find up to 40 percent of his calls blocked. We have estimated that the total cost of time wasted redialing AUTOVON calls may be as much as $18 million per year. In

[1] A notable exception is the Query/Response service, which limits a subscriber to one to six particular correspondents.

addition, there is the cost of delay in having the message delivered. A dedicated circuit eliminates these costs.

If common-user services are to compete with dedicated circuits, they must do so not only on the basis of *price* but also on the basis of *quality*. Even though a common-user alternative to a dedicated circuit is not generally available at present, it appears to be technically feasible. What is currently called off-hook flash on AUTOVON could be offered to any subscriber and priced at cost. Alternatively it might be possible to partially dedicate backbone trunks, allowing their capacity to be used by the network where not required by the subscriber.[1]

B. FULL-COST PRICING

The second target of our analysis was the relationship between the total cost of providing DCS services and the prices subscribers pay for them. Of the total $993 million estimated cost of DCS services in FY78, $241 million or 24 percent was included in subscriber charges. The remainder was attributable to depreciation of government-owned equipment, R&D expenditures, O&M, and overhead. The percentage of cost included in charges varied according to system from nine percent for dedicated circuits to 74 percent for AUTODIN. It also varied by region within each system.

The remainder of the cost was paid by subscriber agencies, but in a manner that tended to separate the price paid from the service used. The manner in which user charges are set and costs are paid results in massive distortions of the prices subscribers pay for services both within the DCS and between the DCS and commercial carriers. In particular, dedicated circuits are underpriced.

[1] Such services would be designed to prevent interference with the command-and-control usage of the networks.

Nearly all of the costs not paid through the Communications Services Industrial Fund (CSIF)--approximately $750 million in FY78--are included in the budget of one of the defense agencies. But the equipment they pay for does not necessarily correspond to the services they use. As a result, some agencies are currently subsidized by others. In addition, non-defense users of the DCS are subsidized since they usually pay for none of the purchased equipment.

C. DECENTRALIZED FUNDING OF PROCUREMENT

The third major topic we analyzed, and the one for which we found the least evidence leading to definite conclusions, is the advantage of centralized procurement funding compared to the current decentralized funding procedure. It is argued that the configuration of the government-owned portion of the system and the composition of capital equipment would be more nearly optimal if procurement funding were done centrally through the CSIF. On the other hand, subscribers stress that their participation in the procurement process imposes constraints which assure that DCA is responsive to the needs of its subscribers. Which view more accurately reflects current reality is not readily apparent.

The question of which procurement funding process is more desirable in many ways is bound up with decisions on how services are defined, priced and supplied. As long as a significant portion of the services offered on the DCS is linked to equipment that is procured by individual defense agencies, there is a large incentive for these agencies to desire a major role in procurement. Procurement and the purchase of services are synonymous. Only if services are defined, priced and supplied in such a way as to divorce them, in the subscriber's perception, from the procurement of equipment is it likely that the defense agencies will feel comfortable with centralized procurement funding.

If full-cost pricing were to be adopted and new services defined and offered at the cost of providing them, centralized accounting would be required. In this case, centralized budgeting for procurement would reduce the need for duplicate accounting and the extent of cross-reimbursements among defense agencies. This simplification of accounting procedures would be a beneficial supplement to the potential economies resulting from better system configuration through centralized procurement.

D. RECOMMENDATIONS

Based on the analysis outlined above, we have made a number of recommendations and observations. Earlier audits and studies done by the GAO and others have pointed out inefficiencies in the operations of the DCS and recommendations have been directed at removing them. In most cases, however, they have suggested that the preferred solution is more control by DCA over the decisions made by agencies. They have tended to ignore the effects that incentives might have upon the decision-making process and, in turn, upon the efficiency with which services are selected and provided. Our recommendations, on the other hand, have as their central objectives the dissemination of knowledge about the costs of providing service and the creation of incentives to which decision-makers can respond. We believe that if efficiency is to be improved, it must occur with the active participation and agreement of users. It is unlikely that this can be accomplished simply by taking away the users' decision-making powers. Finally, although some of these proposals may have important non-economic effects, those effects are outside the scope of this study and we did not take them into account.

1. Pricing and Definition of Services

• Private-Line Service on Common-User Networks

The major manifestation of inefficiency that DCA must contend with currently is controlling what appears to be a proliferation of dedicated circuits. In order to do so effectively, however, DCA must recognize that a large part of this problem arises because many users perceive the price/service combinations provided by dedicated circuits to be preferable to those offered by common-user networks. The economically efficient solution to this problem is unlikely to involve simply limiting the number of dedicated lines authorized, but rather improving the price/service combinations offered on common-user networks. To do this DCA must determine accurately when a dedicated circuit is more expensive than a common-user alternative and convince the subscriber he is at least as well off with the common-user service as he is with the dedicated circuit. Achieving this goal will require a number of steps. First, DCA must define and assure itself of the technological feasibility of a private-line service on the common-user networks which duplicates the service offered by a dedicated circuit. Second, it must develop a methodology for accurately computing the total costs of both alternatives--dedicated circuits and common-user private-line service. Third, it must create a charging system that will translate those costs into the prices that subscribers pay in order that they face the true costs of services they buy. If these steps are accomplished, future choices between dedicated circuits and common-user network services can be based on correct information about economic costs.

The steps have different implications for AUTOVON and AUTODIN. AUTOVON is currently used at full capacity. The calculated cost of providing private-line service must include the cost of expanding that capacity. AUTODIN, on the other hand, has excess capacity. This means that there is some flexibility in the pricing of service on AUTODIN and the prices could be set so as to increase utilization of present capacity while generating revenue to help cover the fixed cost.

- **Development of an Inventory of Dedicated Circuits**

Once a private-line, common-user service is developed and a methodology chosen for pricing it, subscribers should find it an easy task to compare its cost to that of each new dedicated circuit proposed. Inertia or other factors, however, may prevent subscibers from making the same comparison for each of their current dedicated circuits. DCA can aid subscribers as well as increase its own managerial capability by creating an inventory of dedicated circuits and their costs. Part of the information for each dedicated circuit or network should include specification of the characteristics and costs of the common-user network that could be used as an alternative. Costs can be compared in order to determine which of the current dedicated circuits are logical candidates for replacement by common-user services.

- **Usage-Sensitive Pricing**

Economic efficiency requires that subscriber charges differ when and to the extent that the costs of providing the respective services differ. Subsidizing one subscriber at the expense of another produces incentives which cause users to behave inefficiently. Such subsidization almost invariably occurs when costs are averaged to obtain user charges which are fixed and independent of usage. Subscriber charges for the common-user, switched systems should depend not only on connectivity but also on factors such as the amount, duration, distance, direction, timing, and precedence of usage, all of which affect costs.

The charges should be assessed at the level of the communications commands of the military departments, providing incentives to configure requirements so as to minimize government costs of satisfying user needs. The communications commands, in turn, may provide at their discretion incentives to operational commands to evaluate and restrict the calls or messages of individual users. Individual users could be controlled by means of PBX service restrictions and/or administrative procedures. While the individual user need not be billed, information on his specific calls would be available.

Adoption of usage-sensitive pricing would lead not only to more efficient use of the common-user system but also would help reduce dependence on dedicated circuits since it effectively permits subscribers to tailor the services they pay for and consume more closely to their needs. Due to the long-term nature of the investments involved, however, subscriber charges should provide long-term planning guidance and thus should not fluctuate in response to temporary conditions of excess capacity or congestion.

- **Installation of AMA Equipment**

Information is currently generated which would permit usage-sensitive pricing to be adopted on the AUTODIN system. AUTOVON, on the other hand, would require the installation of Automatic Message Accounting (AMA) capacity throughout. Whether it is worth the cost of installing such equipment now could be determined only by comparing its cost (at present an unknown) with the benefits of what it might accomplish. We do strongly recommend, however, that any new equipment installed in the DCS include AMA capacity and that it be put into operation as soon as feasible. The information generated by AMA would be useful not only for billing purposes but also as an extremely valuable management tool for DCA.

- **Restricted Services**

As a less flexible alternative or adjunct to the above proposal on usage-sensitive pricing, the common-user switched networks could offer services which restrict network access more narrowly than at present. Community-of-interest restrictions could include smaller calling areas, calling areas defined in terms of distance bands (like WATS), or specification of the particular numbers a subscriber could call. Time restrictions could include allowing access only during certain pre-arranged periods, such as non-busy hours or particular hours during the business day. Subscriber charges would reflect differences in the government costs of providing the various services. Restricted services, therefore, would provide better incentives for subscribers to consider the effect of the distance and timing of calls on government costs. Further, restricted

services would reduce the availability of the networks for unjustified calls, since subscribers would acquire services more closely tailored to their legitimate needs. Implementing restricted services would require software and/or hardware changes at the network switches.

- **New Common-User Services**

  In addition to the provision of private-line services on common-user networks, DCA should consider developing and implementing some new alternative services for its subscribers. This study has not determined the feasibility of particular new services, but examples of the types of services which should be considered include:

  - Administrative precedence or guaranteed grade of service, provided without command-and-control justification to subscribers willing to pay incremental cost (on AUTOVON or AUTODIN, permanent or peacetime only, assuming no degradation of service to other users or interference with command-and-control requirements);
  - Data-conditioned AUTOVON trunks for data and secure-voice transmission;
  - Off-peak wideband service, using AUTOVON voice trunks;
  - Combinations of these services with particular community-of-interest and time-of-day considerations.

2. Full-Cost Pricing

- **Inclusion of All Economic Costs**

  Charges for DCS systems should reflect the relative economic costs of the services provided. The present practice of excluding overhead (other than DECCO), military personnel costs, and depreciation expense on government-furnished equipment results in serious distortions. Systems furnished mainly by commercial lease contracts have subscriber charges which reflect most of the economic

costs. There are no subscriber charges, however, for services furnished entirely by government-owned equipment. Such discrepancies provide incentives for subscribers to choose systems with low subscriber charges rather than low economic costs to the government. Accordingly, DCA should consider adopting subscriber charges for all DCS services and these charges should reflect all economic costs (including overhead, military personnel, and depreciation on government-furnished equipment).

- **Accounting Procedures**

  Practical management considerations should dictate the way in which depreciation, military personnel expense, and overhead are incorporated into subscriber charges to achieve full-cost pricing and the way in which cash flows from subscribers are channeled into various budgets. There are at least two possible ways this can be accomplished:

  - Costs could be reimbursed by the CSIF to the military departments which currently fund them, perhaps as a credit against their subscriber charges for using DCS services.

  - CSIF funding could be extended to additional items (e.g., procurement), and the associated outlays recovered by subscriber charges.

  The second alternative would certainly be less complicated from an accounting and budgetary point of view. But the first alternative also appears feasible, so that full-cost pricing does not necessarily imply centralized funding of procurement and other costs.

3. Funding Procurement

The present, decentralized method of funding DCS procurement is inefficient in two respects:

- Military departments responsible for funding procurement in particular areas cannot always be responsive to the needs of other military departments and defense agencies;

- Decentralized procurement increases government costs by inhibiting coordination and system design for DCS facilities.

But centralization at DCA of responsibility for funding DCS procurement would lead to other problems:

- Centralization would reduce the present ability of military departments to be responsive to their own needs;
- DCA would face less pressure to properly justify its procurement proposals.

It is difficult to measure the economic costs associated with decentralization of procurement funding, or to predict those associated with centralized funding. In principle, the checks and balances inherent in the present system could prevent any serious problems. To the extent that inadequate coordination leads to higher government costs, the problem might be solved by better procedures. But, if lack of responsiveness to needs between military departments is a serious problem, then centralization of procurement funding is almost certainly a part of the solution.

Chapter I

INTRODUCTION

A large number of management audits and studies have been performed by the General Accounting Office (GAO), the Defense Audit Service, and others over the past ten years which have concluded that there exist certain inefficiencies in the operations methodology of the Defense Communications System (DCS).[1] The major observations and recommendations of these studies can be grouped under three headings: (1) definition, adequacy, and pricing of services; (2) full-cost allocation and subscriber charges; and (3) decentralization of procurement funding.

In this study we have examined these three problem areas, with emphasis on the first, in an attempt to evaluate the validity of certain observations and to conceptualize some potential solutions. For example, one of the principal conclusions drawn in a number of studies about *the definition, adequacy, and pricing of services* is that too many dedicated circuits exist and that total costs would be reduced if more subscribers were required to use common-user networks rather than dedicated lines.[2] Unfortunately, if such a recommendation were implemented, with no other changes in the system or services offered, serious problems would arise. Subscribers choose dedicated circuits because they prefer them to the available alternatives; forcing them to accept alternatives will not make those alternatives any more desirable.

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[1] See Appendix A for a description of these studies and their recommendations.

[2] See, for example, GAO, *"Better Management of Defense Communications Would Reduce Costs,"* December 14, 1977.

The preferred solution to this dilemma requires that the common-user alternative be made more attractive than the dedicated circuit. If, as the studies argue, it is possible to provide service equivalent to a dedicated circuit on the common-user network at less cost to the government than the price of the dedicated circuit, the subscriber should be asked to pay only this reduced cost. It is upon this premise that we have based our evaluation of the choice of services, attempting to broaden the analysis to go beyond the question of dedicated circuits alone and examine, in a conceptual way, the possibilities that exist for redefining and repricing other services. We have concluded that the principal problem is not that users have too much freedom of choice and that this freedom should be restricted, but that the range of services over which choice can be exercised is too small and that the menu should be lengthened and some prices changed so that a wider variety of requirements can be satisfied more exactly.

In analyzing *full-cost allocation and subscriber charges*, we have used as a starting point the two previous IDA studies which examined the price structures of AUTODIN and AUTOVON.[1] We have gone beyond them, however, in attempting to estimate the magnitude of capital and other costs that are neither included in the CSIF nor recovered through subscriber charges. Using these estimates, we also evaluate the degree to which user charges understate the true cost of service and the amount of cross-subsidization that exists among subscriber agencies.

In our examination of the *decentralization of procurement funding* we encountered two conflicting arguments. On the one hand there was a feeling that the configuration of the overseas networks and the composition of capital equipment would be more

[1] See W.F. Beazer, et al., *Cost Allocation for AUTODIN: An Economic Analysis*, IDA S-487, Institute for Defense Analyses, September 1978 and W.F. Beazer, *Pricing and Cost Allocation for AUTOVON*, IDA S-506, Institute for Defense Analyses, forthcoming.

nearly optimal if procurement were funded centrally through the Communications Services Industrial Fund (CSIF). On the other hand, subscribers argued that their participation in the procurement process imposed limits which assured that the Defense Communications Agency (DCA) was responsive to the needs of DCS subscribers. Which of these views more accurately reflects reality is not readily apparent.

Having analyzed the three problem areas we have made recommendations which attempt, at the conceptual level, to provide insights into potential solutions for the inefficiencies that are present in the DCS. With respect to the question of definition, adequacy and pricing of services, our recommendations are aimed primarily at creating desirable common-user alternatives to dedicated circuits. On AUTOVON, for example, it is technically feasible to provide high-grade, point-to-point service that is directly comparable to a dedicated circuit. Each communications requirement would need to be analyzed separately, but in many cases the cost of such private-line service on a common-user network would be much less than the cost of a dedicated circuit. Although in some instances non-economic considerations will be overriding, the decision on which routing to use, dedicated or common-user, should normally be based on cost. The price charged the subscriber should also reflect cost. Subscribers should readily accept and even prefer private-line service on common-user networks if the price they pay is at most (and usually less than) what they would pay for a dedicated circuit, especially if the quality of service can be made identical.

We also recommend that serious consideration be given to integrating all costs, including O&M and capital costs, into the pricing structure for services. This would eliminate cross-subsidization among agencies, provide better information about the true costs of services, and lead to more efficient choices by DCS subscribers.

The question of responsibility for DCS procurement appropriations is more difficult to answer without better measures of the inefficiencies which result from the present system. Both centralization and decentralization have advantages with respect to the responsiveness of DCS service to user needs and the efficiency with which services are produced. It should be noted that implementation of the recommendation above on full-cost pricing would be facilitated by centralized funding of DCS procurement.

We have not offered specific recommendations about how to deal with the very difficult problems associated with implementation of these policy recommendations. We are aware that there are a number of non-economic goals that are important to the military departments and that these impinge significantly upon the size and operations of the DCS. The analysis contained in the study is restricted to the economic aspects of the DCS.

The study is organized in the following way. Chapter II provides a review of the services offered on the DCS and of the role played by DCA and by subscribers in its operation. The third chapter analyzes the three problem areas outlined above and, in the process, provides rough estimates of the cost of congestion and of the potential savings available from reducing subscriber dependence on dedicated circuits. The fourth chapter discusses solutions to the problems and evaluates potential benefits from adopting them. Chapter V includes conclusions, observations, and recommendations.

Chapter II

DCA AND ITS CUSTOMERS

Military departments and other defense agencies use communications services to support the performance of their missions. They are customers, shopping for services, and making their selections based on the features, qualities, and prices of the services available. A variety of long-haul transmission services are available within the Defense Communications System (DCS) ranging from common-user switched service to private-line service on dedicated circuits. Defense customers choose from among these services, as well as from services defined to be outside the DCS. The Defense Communications Agency (DCA) is a supplier of transmission services, acting as manager of the DCS. In this capacity, DCA contracts with commercial common-carriers for some services, and coordinates the provision of other services by the military departments to themselves and to each other.

Understanding these relationships is integral to the analysis of DCS efficiency in this study. Accordingly, we provide background information on the following topics:

- transmission service needs of defense users,
- transmission services available within the DCS, and
- management of the DCS and determination of its costs.

Within this chapter, references are made to more detailed background information contained in several appendices.

A. TRANSMISSION SERVICE NEEDS OF DEFENSE USERS

This section focuses on the users of transmission services and their needs. The topics to be covered include:

- the concept of user needs and the possibility of alternative arrangements for satisfying those needs;
- the multi-dimensional character of user needs; and
- the methods by which military departments choose services and allocate their communications budgets.

1. Alternative User Needs

User needs for communications services are based on the support such services provide to the performance of user missions. But there are usually several ways in which a military mission can be performed, giving rise to several different ways of defining communications needs. Because of budget considerations, the method chosen to perform a mission depends, in part, on the costs of the various methods available. Accordingly, the communications needs of a particular user are influenced by the cost of the various communications services which can be used to accomplish a designated mission.

For example, an organization may have the choice of processing information at one central location or at each of its many field locations. Processing is likely to cost less at the central location becuase of the larger scale of operations, but whether centralized processing is more efficient overall depends upon the cost (both in time and money) of transferring the information to the central location. If communications costs are low, the organization will frequently decide to transfer large amounts of raw information over long distances to the central location. If the communications costs are high, however, processing will likely be accomplished in a large number of smaller facilities in a decentralized fashion, making less use of communications services.

The point of the preceeding example is that the cost of communications services is an important consideration in the determination of an organization's needs. While the performance of a mission may be an absolute necessity, there is almost always room for choice in deciding what communications services to use in support of that mission. Thus, the problem facing the user with limited resources available is to choose from among the available communications services to support his mission in the most effective way.

2. Characteristics of User Needs

Well-defined communications needs are multi-dimensional in character. They are specific with regard to many different characteristics of the needed service. These include such factors as the form in which information is to be transferred, the timing and volume of the transfer, the geographic locations involved, as well as the quality, the reliability, the survivability and the availability of the service. Following is a brief discussion of these basic dimensions of user needs. (A more detailed discussion is included in Appendix B.)

a. Transmission Capability

Transmission capability refers to the basic type of transmission service required. User needs in this area are based on the types of information to be transferred and the way in which the information will be used. Such end-use considerations determine the types of signals users generate, and hence the specific transmission services required from the DCS.

While the information-carrying characteristics of a circuit actually depend on technical factors such as bandwidth and conditioning, users usually request circuits in terms of their intended use. For example, to transmit ordinary voice signals (between telephones), users specify needs for voice-grade

circuits, which imply bandwidth and conditioning levels adequate to transmit voice signals so that they are intelligible to the recipients. Similarly, to transmit data signals, users request circuits in terms of transmission line-speeds (i.e., the number of bits of information transmitted per second). Such requests imply bandwidth and conditioning levels adequate to transmit the data signals at acceptable transmission error rates. The lowest line-speed requirements are for telegraph equipment and control signals for mechanical devices, while the highest line-speed requirement is for the transmission of color-television signals. The line-speed requirements for applications involving computers cover a wide range of transmission line-speeds.

b. Delivery Time

Delivery time measures the elapsed time between the dispatch of a message and its receipt at the destination.[1] When the transmission service is provided by a direct circuit to the destination, delivery time depends on the amount of information to be transferred, the line-speed capability of the circuit, and the geographic distance to the destination. When the transmission service is provided by a message-switching network, however, no direct connection is established between origin and destination. Additional delays may be introduced because of the message-switching process and the possible storage of messages enroute to their destinations when the network is congested. User needs regarding delivery time depend on the importance of timely receipt of the information.

c. Availability of Service

Availability of service refers to the conditions of access, in particular--is the service available when the user needs it? There are a number of different availability characteristics to

[1]Delivery time on AUTODIN is also called speed of service.

consider. Even under normal conditions, facilities may become congested so that users must endure some delay before they can use a transmission service. A common measure of this delay for circuit-switching networks is the grade of service, which is the probability that a request for service will be blocked. For packet-switching networks, availability can be measured by average or maximum waiting time before transmission begins. Extreme cases of service delay occur when technical failure or hostile action cause transmission facilities to break down. This aspect of service quality is measured by the extent to which the transmission technology and facilities are reliable, redundant, and survivable.

User needs vary with regard to the availability of transmission service. The major determinant of needs in this respect is the importance of the information to be transferred and the consequences on the efficiency of the recipient's activities (which depend upon this information) if the message is delayed. The most important purpose of rapid communications service is command and control or the direction of combat operations. Intelligence communications are also judged to be very important. Fast service is generally considered least important in regard to administrative purposes.

When the information to be transferred is both critically important and needed quickly, communications needs are defined in a very exacting way. Transmission service must be available without delay and the probability of the user being blocked must be virtually zero. In other cases, however, the information transfer may support a less important mission or may not be needed at the destination immediately, so that the cost of the best level of service is not justified. Operational efficiency may also lead users to define their needs in a very exacting way, especially when computer applications are involved.

A central problem in planning for user communicaitons needs is the contingency nature of most high-priority requirements. Users define their needs so that transmission services are adequate to handle requirements during periods of crisis. At the same time they provide for (usually different) needs during non-emergency periods, and for low-priority needs during emergency periods.

d. Community of Interest

The community of interest for a particular user is the set of destinations with which that user needs to communicate. The dimensions of the community of interest depend on the user's mission and vary greatly among users. The set of correspondents in the community may be stable or may vary over time. There may be many or few correspondents and they may be concentrated within small geographic areas or else widely dispersed. Distances among correspondents may be small or great. The community may parallel other defense communities or it may be relatively isolated.

Correspondents within a community of interest may be located at defense or other government locations as well as at private facilities. Communities for incoming information may differ from those for outgoing information. And finally, the amount of information traffic to particular correspondents may vary considerably. It should be noted also that the size of the community of interest itself is influenced by the cost of communications services.

e. Timing and Amount of Use

User needs for transmission services also vary with regard to timing, frequency, predictability, volume and permanence. For example, some users send a large volume of messages each business day, while others send no messages until a crisis occurs.

The characteristics discussed above are all relevant to the problem of defining user needs. Exactly how user needs should be specified with regard to these characteristics depends, in part, on what services are available and their cost. The efficient choice of transmission services is determined by comparing the costs of alternative specifications of need with the values of the alternative levels of mission support they provide. Subscriber costs include DCS subscriber charges, as well as lease or other charges for access lines and user-oriented terminal equipment.

3. The Choice of Communications Services by the Military Departments

In the previous sections, the military users' needs for communications have been discussed; in this section, the process by which the users' needs are translated into purchased communications services will be reviewed. General issues will be discussed here and a brief description of the procedures used in each of the military departments is included in Appendix C.

Because needs are multi-dimensional, it is difficult for anyone other than the user to determine what contributions alternative services make to mission performance. But because costs are affected by the ways needs are defined, it is important that fiscal responsibility be brought to bear on the definition process. Thus, the problem for military departments is to mesh both of these considerations.

In all military departments, users typically specify the means of satisfying their communications requirements. These requirements are expressed formally in a Request for Service (RFS) which must be *validated* as to need. If the proposed request costs more than $200,000 per year to lease or more than $500,000 to buy, the Office of the Secretary of Defense must approve the request; smaller requests are approved within the

military departments. Once validated, a requirement must be *certified*. This involves determining whether the method of satisfying a requirement is compatible with existing technology and whether funds are available. Once certified, the RFS becomes a Telecommunications Service Request (TSR) which is essentially a purchase order. The TSR is sent to the appropriate DCA office for implementation.

Most communications requirements are funded in the budgets of the communications commands[1] of the respective military departments.[2] Since actual budgets are typically smaller than the amounts requested, not all requirements can be funded. To a large extent, the communications commands are responsible for allocating funds among requirements. Thus, the communications commands, in their attempts to stretch the limited communications dollars, are perhaps the lowest level of price-responsiveness in the military departments (with the exception of the Air Force's new program wherein major commands are responsible for allocating certain funds among non-switched communications services). While users may be cost-conscious, the communications commands face real budget constraints which cannot be exceeded. As budgets are tightened, however, the communications commands are likely to transfer this pressure down to lower levels by turning down more requests and by searching for cheaper methods of satisfying user requirements. It might be expected that users will become more and more price-responsive and cost-conscious with tightening budgets even though they do not directly pay the bills.

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[1]The communications commands are major commands within each military department, responsible for supporting the communications requirements (DCS and non-DCS) of their respective military departments.

[2]If a request is not in cycle with the usual Planning, Programming, and Budgeting (PPB) System, the user must provide his own funds for the project.

B. A DESCRIPTION OF DCS SERVICES

1. Methods of Providing Services

The Defense Communications System (DCS) provides a wide range of long-haul transmission services to support the communications needs of military departments and other government agencies. There are three principal ways in which DCS provides these services: circuit-switching, message-switching, and dedicated circuits.

Under circuit-switching, a network circuit is temporarily switched to form a direct, end-to-end link between the sender and receiver of the communication. The circuit can be used for both voice communication and data transmission. Interactive communications are possible because of the end-to-end connection. Circuit-switching networks provided under DCS include AUTOVON, AUTOSEVCOM and ATSS.

Under message-switching, the user's information is stored at various network switches and forwarded to the intended destination as circuits become available on the network. Message-switching arrangements allow the transmission of both teletype messages and data. With certain exceptions, the sender of a communication on a message-switching system is not in direct contact with the receiver at the time the message is sent. On AUTODIN, this limits the possibility of direct interaction among individuals and/or computers on the network. But ARPANET, WIN, and AUTODIN II are DCS message-switching networks that use the new packet-switching technique. This method permits packets of information to be switched and transmitted so rapidly that users can interact as though they were directly connected by a circuit.

With dedicated circuits, a permanent, end-to-end connection is established between two or more users. Dedicated circuits are used by customers who have very narrow communities

of interest with which to communicate, or by users who have special needs which cannot be satisfied on the switched networks. All types of messages including voice, teletype and data can be transmitted on appropriate dedicated circuits.

2. Systems

The following discussion describes the transmission services provided by the various DCS systems. This discussion will include a brief description of each system's transmission capability, delivery time, availability of service, and community of interest served. A more detailed description of these services is contained in Appendix D.

a. AUTODIN

This network provides a message-switching service for both messages and data. AUTODIN's primary purpose is to provide communications support to command-and-control systems and certain intelligence programs. When capacity exceeds that needed for these purposes, it is available for logistics, personnel and other administrative applications. A precedence system is used to identify important messages and to ensure that the command-and-control function is not hindered by the other uses of the system. The various precedence levels (Flash, Immediate, Priority and Routine) are assigned to messages in accordance with criteria established by the JCS. Messages are transmitted in order of precedence, and flash messages can preempt the use of AUTODIN circuits when necessary for timely delivery.

Access lines may be connected at up to 4,800 bits per second in line-speed capability, but the store-and-forward feature reduces effective end-to-end line-speed on AUTODIN substantially below that level. Service is almost always available since there is little or no delay in entering a message into the system. Congestion, to the extent that it exists,

occurs at the message destination.[1] The delivery time for a message depends upon the overall usage of the system and the level of precedence attached to the message. The speed of service objective for flash messages is ten minutes or less, while routine messages (the lowest priority) are targeted for three hours or the start of the next business day.

The community of interest served by AUTODIN is worldwide, with 1,200 subscribers and over 5,000 addressable destinations. The system is divided geographically into CONUS, Europe and the Pacific. At present, it is generally agreed that AUTODIN is sized large enough to handle all of its designated functions, and there may be considerable excess switching capacity within the system.

b. ARPANET and WIN

These are special-purpose, packet-switching networks, designed to provide transmission line-speeds suitable for interactive computer applications and for the transfer or sharing of large data files. ARPANET is intended to support defense and communications research, while WIN will support command-and-control systems. The ARPANET system is concentrated in CONUS and certain areas in Europe, while WIN will be a worldwide system.

Packet-switching networks are designed for the rapid transmission of data packets and provide very little capacity for storing data on the network. To avoid network congestion during busy periods, users are regulated as to the rate at which they may transfer information to the network. Thus, congestion will be evidenced by reductions in end-to-end line-speed. In some cases, congestion will force users to wait before beginning transmission.

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[1] Most congestion occurs at origin and destination message-processing stations rather than at the network proper.

c. AUTODIN II

This packet-switching network (which will become operational in December 1979) will eventually replace ARPANET, WIN, and a number of dedicated circuits. It will provide rapid two-way transmission of computer data and the capability to transmit bulk data on an intermittent basis. Some 65 smaller networks using dedicated circuits are candidates for replacement by AUTODIN II.

A precedence system will be used to provide preferential treatment for priority uses. No formal objectives have yet been established for end-to-end line-speed or maximum waiting time. The AUTODIN II system will encompass CONUS and eventually include various overseas locations, with 556 subscribers expected the first year. By the mid-1980s, AUTODIN and AUTODIN II are scheduled to be integrated into a unified system. Until that time, while they will have interconnections, they will operate as separate systems.

d. AUTOVON

This major network provides a common-user circuit-switching service. The end-to-end circuits are used primarily for voice transmission and certain types of data requirements. Except for a few data-grade circuits overseas, the conditioning of AUTOVON circuits precludes many computer applications. As with AUTODIN, AUTOVON's primary function is to provide communications support for command-and-control operations. In addition to this function, it is available for business traffic during non-emergency periods. In fact, business requirements cause the CONUS portion of AUTOVON to be much larger than would be required for command-and-control purposes alone.

A precedence system similar to that used on AUTODIN is in force. It differs in that a maximum precedence authorization is designated for each access line; also, any precedence call

attempt can preempt a circuit being used for a lower-precedence call, if necessary. Since AUTOVON is a circuit-switching network with end-to-end connections, there is no delay in transmission once a circuit is obtained. Congestion is manifested by difficulty in completing calls (i.e., obtaining circuits or avoiding preemption) and the necessity of frequent redialings. The level of congestion on AUTOVON is very high compared to most commercial telephone systems, with the percentage of call attempts not completed ranging from 30 to 40 percent in a sample taken in 1978. The grade of service for the AUTOVON backbone is targeted at P13 (i.e., there is a 13 percent chance that a call attempt will be blocked) in CONUS, and is much higher on certain transoceanic routes. When congestion on access lines is also taken into account, the overall grade of service is even worse. As a consequence of this congestion, precedence escalation has occurred in some areas, with callers using higher levels of precedence than would be warranted by the content of their calls.

AUTOVON is a worldwide network divided into three regions: CONUS, Europe, and the Pacific. It is also interconnected with several smaller defense-oriented systems, and, under certain conditions, with commercial telephone networks. There are approximately 17,000 subscribers to the AUTOVON system. Each subscriber, however, may represent many potential users since the AUTOVON line may be connected to a switchboard or other multiple-access arrangement.

There seems to be rather general agreement that the system is severely congested at present, with the precedence system working only imperfectly to allocate access to the system. In addition, data users complain of the poor quality of transmission once access is obtained.

e. AUTOSEVOCOM

This circuit-switching network is designed to provide secure-voice communications to defense and other government users. Because of the encryption process, voice conversations are transmitted as digital signals. Thus, considerably better conditioning is required than would be needed for normal voice communications. Many AUTOSEVOCOM calls are routed over the AUTOVON network. Because of inadequate AUTOVON circuit conditioning, the quality of voice reception is frequently quite poor.

Since most AUTOSEVOCOM calls are routed over AUTOVON trunks, the AUTOVON congestion problems discussed above apply here as well. But important calls receive preferential treatment, since the usual AUTOVON precedence system applies to secure-voice calls routed over the AUTOVON backbone. The AUTOSEVOCOM network includes over 1,500 subscribers worldwide.

f. ATSS

The Alaska Telephone Switching System (ATSS) provides a circuit switching service among subscribers in Alaska, providing circuits suitable for voice transmission and certain data requirements. It is interconnected with AUTOVON by means of access lines from ATSS switches to AUTOVON switches in CONUS. The ATSS switches are so old that the system has no preemption capability. There are 471 subscribers to the system.

g. Dedicated Circuits

These circuits provide private-line transmission service for both voice and data. Some dedicated circuits are leased from common carriers, while others are derived from government-owned facilities or from leased systems managed by DCA. A wide range of service characteristics are available for users of dedicated circuits. This is a major advantage of using

dedicated circuits, since they can be tailored directly to meet user needs.

Since the users of dedicated circuits are permanently connected with one another, the circuits are always available. The only congestion which arises is within the organization using the service, not on the circuit itself. Dedicated circuits can provide line-speed capabilities of millions of bits per second. The reliability of dedicated circuits depends somewhat on the technology used to provide them. Dedicated users can establish systems which encompass almost exactly their own community of interest. When this group is large and geographically diverse, however, dedicated circuits can be a very expensive arrangement to meet the group's needs. Dedicated circuits are generally available on a worldwide basis.

C. THE SUPPLY OF DCS SERVICES

In this section, attention will focus on management of the supply of defense communications services. First, the rationale for having these services provided in a centralized fashion will be discussed. This will be followed by an examination of the organizational structure of the DCS. The section will conclude with a brief discussion of costs and subscriber charges for various DCS services.

1. Cost Advantages of Centralization

The Defense Communications System was established primarily to take advantage of certain economies of centralization. A centrally managed system provides the same services as those provided by the separate systems of the military departments, but at a lower total cost. This section discusses the important potential sources of these cost savings.

- One such source is defined by economists as *increasing returns to scale*, which refers to a situation

where a proportionate increase in each of the resources needed for production permits a more than proportionate increase in output. For example, it might cost less to provide services on one large system than on three smaller systems producing identical services. Such economies of scale can be explained by technical factors inherent in the methods of production, or by the fuller utilization of certain resources which cannot be purchased in small amounts (indivisibilities).

- Cost savings may also result when the production of several different types of service are centralized in one organization. These savings, labelled *economies of scope,* occur when various services can be produced at less cost when produced together as compared to their separate production. For example, it might cost less to provide service to different communities of interest on one network than on separate networks, or one network for both data and teletype communications may be less costly than having a separate arrangement for each service.
- Other potential cost advantages of centralization can result from volume discounts and minimum requirements that arise when services are purchased from common carriers. These are economies in the acquisition, not the production, of the services. A centralized arrangement may also be advantageous when interdependencies exist among consuming or producing organizations, as is the case for military users. (For a more complete discussion of economies of centralization, see Appendix E.)

The specific centralization economies which are relevant to the DCS are in the following areas: circuit production, circuit acquisition, and circuit utilization. The transmission of communications signals (*circuit production*) is characterized by important increasing returns to scale in that transmission capacity between two points can be increased at a rate proportionately greater than the rate at which associated costs increase. These technological scale economies are realized by common carriers where DCS circuits are leased, and by the DCS where circuits are provided by government-furnished equipment.

Economies from centralized *circuit acquisition* exist because of the way lease charges of common carriers are

structured. When a large amount of circuit capacity is leased between two points, savings of as much as 50 percent can be realized through the TELPAK volume discounts. DCS multiplex systems (which effectively subdivide a large circuit into a number of smaller ones) are another source of savings which result from the structure of commercial leases. While the common carriers can and do employ multiplexing themselves, the resulting cost savings are not reflected in their lease charges. Thus, it is often less expensive for DCS to lease a circuit and then use leased or owned multiplexing equipment to derive circuits of lesser capacities.

The major potential source of cost saving resulting from a centralized arrangement such as DCS involves the fuller *utilization* of capacity through circuit-sharing techniques such as networks. Most users of communications services rarely make use of end-to-end circuits on a full time basis. Accordingly, if each subscriber were provided a full time circuit to each communication destination, there would be considerable underutilization of circuits. Centralization of circuits into common-user networks reduces DCS costs by making the proliferation of circuits unnecessary, and by increasing the utilization of the circuits which do exist.

These advantages of centralization derive primarily from diversity among subscribers with respect to the timing and destinations of their communications. Three situations may yield excess capacity in a decentralized system and enable a centralized network to lower total cost through increased circuit utilization; these are: (1) the existence of non-emergency needs which can be satisfied using capacity reserved for wartime communications; (2) the existence of systematic differences among subscribers in the timing of their communications over overlapping routes; and (3) the existence of independently random differences among subscribers in the timing of their communications over overlapping routes.

To take advantage of these differences, the common-user networks employ various switching techniques. These permit trunks to be shared among users by switching circuits (AUTOVON) or switching messages (AUTODIN) to more fully utilize the system's capacity. Finally, it should be noted that sharing arrangements have certain drawbacks, particularly the susceptibility to congestion which no individual user can control.

The advantages of circuit-sharing can be illustrated with the aid of Table 2-1, which is based on a simple model explained in Appendix E. Table 2-1 indicates the average number of circuits per user which would be required to provide a P01 grade

Table 2-1. ECONOMIES OF NETWORK CIRCUIT SHARING

Number of Users[a] (n)	Number of Trunks Per User to Provide P01 Grade of Service[b] Assuming Probability of Use[c] Is: 0.10	0.25	0.50	0.75	0.90
1	1.00	1.00	1.00	1.00	1.00
2	0.50	1.00	1.00	1.00	1.00
3	0.67	1.00	1.00	1.00	1.00
4	0.50	0.75	1.00	1.00	1.00
5	0.40	0.80	1.00	1.00	1.00
10	0.27	0.52	0.82	0.91	1.00
25	0.22	0.43	0.71	0.93	1.00
50	0.19	0.38	0.65	0.88	0.99
100	0.17	0.35	0.61	0.85	0.97
500	0.13	0.30	0.55	0.80	0.93
1,000	0.12	0.28	0.54	0.78	0.92

Source: Based on a model discussed in Appendix E.

[a]This is the number of users who may need to call from a particular origin to a particular destination.

[b]With a P01 grade of service, there is at most a one percent probability that a call attempt between the two points would be blocked.

[c]The probability of use is the probability that any one of n users will independently decide to attempt a call between the two points at the time in question.

of service for calls over a particular route. This average is presented for various numbers of users and for various values of the probability that any particular user will independently decide to call (during some particular time period). As can be seen by reading down a column, the number of circuits required per user declines dramatically as the number of potential users increases. As can be seen by reading across a row, these advantages are weaker when the probability of use increases. Also, note that a large increase in the probability of use (say, due to an outbreak of hostilities) would necessitate an increase of circuits or a deterioration of the grade of service.

2. Management Organization of Supply of DCS Services

The DCS and its component systems are managed by the DCA. Funding, engineering, and day-to-day operation of the DCS involves both DCA and the military departments within DCA's overall management direction. The relationships among DCA and the military departments are complex, with each of these agencies playing more than one role. DCA's primary role is to act as supplier of long-haul communications services to the military departments. The primary role of the military departments (in the present context) is that of customer, obtaining required services from DCA. But to some extent these roles are also reversed. DCA acts as a prime contractor, arranging for the military departments to provide a major share of the required resources and services. Similarly, the military departments act as suppliers, producing communications services for DCA (and hence for their fellow military departments).

The flow of funds within the DCS reflects the complexity of these relationships. Through a planning and review process involving the military departments, the Joint Chiefs of Staff (JCS), and the Assistant Secretary of Defense (ASD(C^3I)), DCA establishes the DCS Five Year Program. This Five Year Program

details planned expenditures for the DCS, by project and appropriation, and indicates responsibility for obtaining the required funds. Military departments and DCA request the required funds through the usual DoD Planning, Programming, and Budgeting process. Funds are appropriated by Congress, and apportioned to the particular components.

Except for O&M, funds are usually obligated by the component to which they are apportioned. For O&M, expenditure is complicated by the existence of the Communications Services Industrial Fund (CSIF). The CSIF is a working capital fund managed by DCA. DECCO uses the CSIF to finance commercial leases for defense communications, including both DCS and non-DCS communications. The CSIF is then reimbursed by the organizations ordering the services.

In the case of the DCS common-user systems, the CSIF is used to finance commercial leases, and to reimburse the military departments for some of the O&M expenses they incur while operating and maintaining common-user facilities. In turn, the CSIF is reimbursed through the payment of subscriber charges by organizations using common-user services. The subscriber charges are calculated by DCA so that the CSIF can break even.

The O&M budget requests of the military departments reflect their dual roles as customers and suppliers of DCS services. That is, the requests include funds with which to pay subscriber charges for the use of common-user systems, as well as funds with which to provide operational support to various DCS systems. Indeed, in many instances, a military department is the primary user of systems it operates.

Further information on DCS Funding for FY78 is reported in Appendix F. Of particular note, DCA itself directly controls $79,782,000, or only ten percent of the total DCS budget.

3. Costs and Subscriber Charges for the DCS

This section provides a brief discussion of the determination of costs and subscriber charges for several DCS systems. A more complete discussion including all systems is included in Appendix F.

a. AUTODIN

In CONUS, and Hawaii, the switching centers are leased and operated by the military departments, but maintained by contractor personnel. The overseas switches are government-owned and are operated and maintained by the military departments. The CSIF is used to finance certain recurring system expenses including: (1) leases and contract maintenance costs; (2) reimbursement to military departments for O&M expenses, including primarily civilian pay and supplies; and (3) DECCO's expenses in operating the CSIF, which are assessed at 1-1/2 percent of the amount financed.

The industrially funded AUTODIN expenses are estimated at $43 million per year, with most of the costs associated with the switching centers. Depreciation on government-owned equipment and the cost of military personnel are not financed by the CSIF, and thus do not enter into the calculation of subscriber charges.

In order to calculate AUTODIN subscriber charges, each type of service is assigned a particular weight. The total number of weighted units is predicted for the fiscal year in question. Then, a charge per weighted unit is determined by dividing the total number of weighted units into a forecast of CSIF expenses for the AUTODIN backbone (i.e., switches and interswitch trunks). The subscriber charge for a particular service is calculated by multiplying the charge per weighted unit times the number of weighted units assigned to that service. It should be noted that charges are based upon

services available to a particular user, not upon the actual amount of usage of these services.

b. AUTOVON

The arrangement for the switches and lines of the AUTOVON system are similar in many ways to the AUTODIN system described above. In CONUS, switches are leased and are operated and maintained by private contractor personnel. Overseas facilities are government-owned, and are operated and maintained by the military departments. The circuits used in the network are leased in CONUS and are both leased and government-owned overseas. In calculating system costs, the lease charges and contractor personnel costs are financed by the CSIF, and reimbursed by means of subscriber charges. This is not the case for military personnel and depreciation on government-owned equipment.

AUTOVON subscriber charges vary with (1) the maximum geographic calling area, (2) the maximum precedence authorization level, (3) the directionality of access lines and (4) the conditioning of the circuits required. These charges are based upon the potential service available to a user, not upon the actual amount of usage of these services.

c. Dedicated Circuits

The provision of DCS circuits is managed by DCA. Requests for individual circuits are forwarded by the requesting agency to an appropriate DCA area office or to DCA headquarters. A suitable channel is provided either from unused capacity of existing systems or by the addition of more capacity. Certain dedicated circuit requests are satisfied by means of satellite transmission. All lease requirements are forwarded to DECCO to take advantage of available volume discounts.

The user charges for dedicated circuits depend upon how those circuits are provided. Users pay the full lease costs for circuits provided by commercial carriers, but there are no charges for circuits furnished by government-owned facilities (e.g., satellites). For circuits furnished through a combination of owned and leased facilities (e.g., multiplex systems), subscriber charges are based only on the lease costs. Where charges do exist, they are based on mileage, bandwidth, and conditioning, among other factors.

Chapter III

THE PROVISION OF DCS SERVICES: MANIFESTATIONS AND CAUSES OF INEFFICIENCY

The aim of this chapter is to describe the general conditions required to achieve the efficient allocation and production of communications services and to identify any current procedures which are inconsistent with the attainment of such efficiency within the DCS. Section A defines the concept of economic efficiency for the DCS. Section B describes some of the manifestations of inefficiency. Section C deals with various causes of inefficiency. Section C.1 discusses how current DCA practices, with respect to the definition of services and certain pricing policies, may inhibit efficient operations. Section C.2 analyzes the problems created by ignoring capital costs and certain other expenses in setting prices, and Section C.3 reviews the general methods by which the procurement of DCS facilities and equipment is funded and discusses how some of these methods are inconsistent with efficiency.

At the outset, it will be useful to distinguish between two concepts, *allocative efficiency* and *productive efficiency*. Allocation decisions deal with determining which communications services should be provided, to whom, at what price, and when. Production decisions concern how the chosen services can be provided at minimum cost to the government.

A. ECONOMIC EFFICIENCY: GENERAL CONSIDERATIONS

In a normal market situation, productive efficiency and allocative efficiency are achieved through the interactions of

consumers and producers, with each group independent of the other. Consumers face a collection of commodities and prices and make their selections of goods and services from among them. Producers face demands and costs and make production decisions on the basis of this information. If the consumer maximizes his welfare and the producer his profits, then overall efficiency is likely to be achieved.

The attainment of economic efficiency in the production of any good or service implies that this good or service is being produced at the lowest possible cost. An alternative and essentially equivalent definition is that for any given level of resources devoted to its production, the largest possible quantity of the good or service is being produced. While no business firm or other economic unit can reasonably be expected to achieve the maximum economic efficiency at all moments in time, approximating to such efficiency can be viewed as a reasonable goal for the management of any enterprise. Allocative efficiency, on the other hand, relies upon consumers making decisions so that the value of the last unit they purchase of any good is equal to the price they pay. If this condition is not met in equilibrium, net benefits can result from either expanding or contracting the quantity of the commodity or service produced.

Applying these general criteria to the production and allocation of communications services by DCA has important implications. First, levels and types of services should be expanded only when the benefits of doing so outweigh the costs. In general, the resolution of the issue of the appropriate size of DCS lies outside the responsibilities of DCA. It is possible, however, for DCS services to be administered in ways which will permit those with budgetary authority to identify true costs and benefits associated with the system. In particular,

services can be provided in ways which make the real costs and benefits they involve as explicit as possible.

Secondly, a necessary condition for achieving cost minimization in the provision and allocation of DCS services is that all resources involved in producing services be "counted" and be valued at their opportunity costs, i.e., what they would earn in alternative employments. This rule should apply both to the resources involved in production and to the resources required to use the service. For example, one of the most important resources used in the provision of DCS services is the time of those transmitting messages, even though the value of that time does not appear in any DCA budget. Similarly, any other DCS input, such as capital, which has value in alternative uses, should be considered as a cost of the system and should be taken into account in pricing and decision making.

B. MANIFESTATIONS OF INEFFICIENCY

Although it is nearly impossible to measure the extent to which productive and allocative inefficiency exists in the DCS or to attach a dollar value to it, there are five major areas in which its presence is evident in varying degrees:

- There appears to be excessive reliance on dedicated circuits, at the expense of common-user systems.
- Dedicated circuits are not always provided in a manner which minimizes total cost to the government.
- Given its current size and capacity, there is less than optimal utilization of AUTODIN.
- There is insufficient AUTOVON capacity relative to demand at current prices, leading to congestion, wasted time, and inappropriate use of more expensive substitutes.
- In some cases, the provision of services using government-owned equipment is neither optimal nor fully responsive to user needs.

These manifestations are somewhat analagous to the symptoms of a disease. One attempts to find the causes of the

disease and treat the causes, not the symptoms. With economic inefficiency as well, it is the sources of the inefficiency and not the manifestations that must be treated. There appear to be six primary sources of inefficiency:

- User charges are not sensitive to usage and do not reflect the cost of service.
- There is an insufficient variety of services on common-user networks and there are few price/quality alternatives.
- Services provided by DCS common-user networks are often of low and undependable quality unless the user has a high precedence assigned.
- Budget incentives of DCS subscribers and actual users are often misdirected or non-existent.
- Full costs are not reflected in most subscriber charges and relative prices are distorted.
- Procurement is decentralized with major users responsible for the acquisition and funding of components of the DCS.

The first four of these sources of inefficiency relate to the problem category we have labelled definition, adequacy, and pricing of services. The last two comprise the remaining two problem categories. It is these sources of inefficiency that must be attacked through policy changes if the manifestations are to be eliminated. Before we discuss in detail the causes of inefficiency, however, we need to examine the prevalence of the manifestations.

1. Excessive Reliance on Dedicated Circuits

It is impossible to determine the fraction of DCS communications that are carried on dedicated circuits and difficult even to measure total expenditures. There is no information, for example, on the degree to which dedicated circuits are used or the amount of traffic they carry, nor is there a complete inventory available at a centralized location. We estimate, however, that approximately $55.7 million of the $241 million spent on leased lines in FY78 was used to pay for

dedicated circuits, and that $632 million of the total DCS expenses of $993 million in FY78 was attributable to such circuits.[1]

It is alleged that the dedication of many of these circuits is unnecessary for the achievement of the DoD's missions and that common-user networks would serve as well and at much lower cost to the government. The main source of such potential economies is the fact that, as a rule, dedicated circuits are less than fully utilized. Although some dedicated requirements involve continuous, full-time transmission (at least throughout the general busy hours), most involve intermittent transmission with substantial periods of idleness. The idle periods are potentially valuable resources, if other users can take advantage of them.

There are a number of circumstances in which dedicated circuits would be necessary and efficient from a purely economic point of view. The requirement might be full-time, giving no opportunity for sharing. Or the requirement might be so unique with regard to geographic location or type of service that no users could be found who needed the same service. Also, common-user switches are located to satisfy overall network needs. As a result, some users are sufficiently distant from a switch that access line costs outweigh the potential benefits of sharing.

But there are a number of reasons why users choose dedicated circuits rather than presently offered common-user services, even though the required services could potentially be provided more efficiently on common-user networks. Among these reasons are the following:

- DCS subscriber charges for various systems do not reflect the economic costs of providing the services and subscriber charges are relatively insensitive to

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[1]See Table 3-10, p.73 (below).

the ways in which individual subscribers use the networks. As a result, it costs some subscribers less for a dedicated circuit than for access to a common-user network even though it would have cost the government less to provide the service on the common-user network.

- Users within military departments are frequently insulated from budgetary pressures as regards communications services. Thus their incentive to choose a cost-effective alternative is weakened.
- The grade of service on AUTOVON is unacceptably poor for many lower-precedence users. They may then acquire dedicated circuits even though, with some modifications, a common-user network could have provided the desired grade of service at lower government cost. Flash users may also be concerned about a potential decline in their grade of service during war times and acquire dedicated circuits to meet this contingency.
- Neither AUTOVON nor AUTODIN provide effective, end-to-end transmission line-speeds which are high enough for many data transmission needs. In some cases it would cost the government less to condition or upgrade lines on the common-user system than to use dedicated circuits.

These causes of inefficiency will be discussed in detail later on.

2. <u>Excessive Cost of Dedicated Circuits</u>

When dedicated circuits are supplied, there are frequently alternative methods, both commercial and within the DCS, for providing them. There is reason to believe that the method which minimizes government costs in each particular circumstance is not always selected by the subscriber. This follows from the fact that the relative prices of dedicated circuits on the various systems do not reflect the corresponding costs to the government of supplying them. For example, it is frequently less costly to the government to provide circuits on DCA-managed multiplex systems than to provide them on government-owned facilities. But since there are subscriber charges for multiplex systems and not for government-owned facilities,

subscribers may have no budgetary incentive to choose the less costly alternative. In addition, some of the decisions on circuitry are made by users within military departments who do not bear fiscal responsibility for their choices.

The cost of providing dedicated circuits is also increased to some extent as a result of the decentralization of procurement. Both DCA and requesting agency subscribers are partially dependent on the military departments to provide facilities for transmission services. Because providers have their own priorities, DCS facilities are not always designed so as to minimize overall costs.

3. Under-Utilized Capacity of AUTODIN

The capacity of AUTODIN switches is under-utilized. As shown in Table 3-1, this capacity can be measured in three ways, connections, transmission line-speed, and buffer memory. First, there is a capacity to connect 3,402 access or trunk lines to AUTODIN switches. Only 1,302 lines are connected, or 38 percent of the available capacity. Second, there is a limit on the total rate at which a switch can send or receive information. At the average switch, only 51 percent of this transmission capacity is used. Finally, there is a limit on the buffer memory at the switches. In CONUS, this memory is permanently allocated to each circuit connected, based on the circuit's line-speed capability. The average utilization rate is 74 percent. Overseas, the buffer memory is allocated to lines dynamically (i.e., as needed), so that the average utilization rate is only 40 percent.

This excess switching capacity represents a recurring cash outflow in the case of the leased switches (CONUS and Hawaii) and a foregone opportunity in the case of owned switches. It seems doubtful that the excess capacity is being held in reserve for increased needs during wartime, especially since

Table 3-1. AUTODIN CAPACITY UTILIZATION

AUTODIN SWITCH	CONNECTIONS USED/AVAILABLE	TPANSMISSION LINE-SPEED CAPACITY (BPS) USED/AVAILABLE	BUFFER MEMORY USED CONUS (ADU)	OVERSEAS
Andrews	142/250	149,850/249,000	78.0%	
Albany	112/250	139,725/249,000	82.4%	
Clark	47/200	24,900/128,000		19.4%
Ft. Detrick	95/250	174,045/249,000	90.5%	
Croughton	85/200	59,550/128,000		46.5%
Guam	27/100	16,275/ 64,000		25.4%
Gentile	73/250	140,000/249,000	75.0%	
Hancock	87/250	114,900/249,000	63.9%	
Camp Drake	57/200	28,275/128,000		22.0%
McClellan	113/250	131,895/249,000	70.6%	
Norton	84/250	144,525/249,000	75.7%	
Pirmasens	93/200	84,165/128,000		65.7%
Coltano	85/200	65,160/128,000		50.8%
Taegu	36/100	29,925/ 64,000		46.7%
Tinker	116/250	162,375/249,000	86.1%	
Honolulu	50/250	54,300/249,000	43.5%	
TOTAL	1302/3402	1,519,865/3,009,000	74.0%	40.0%

Source: DCA

the capacity is excessive with respect to maximum use of every line currently connected. Nevertheless, the existence of surplus switching capacity does enhance the survivability of the system, since it permits a larger number of subscribers to be rehomed in the event of a switch breakdown.

The presence of this excess capacity is particularly wasteful in that the cost of using it would be close to zero. And yet, many subscribers pay for leased dedicated lines rather than pay the AUTODIN backbone costs. Part of the reason for excess capacity is simply that the system is too big and could not be fully utilized under any reasonable circumstances. But there are a number of reasons why it is utilized less fully than it could be. These include:

- AUTODIN subscriber charges are insensitive to usage, making it relatively expensive to subscribers whose needs are modest.
- AUTODIN subscriber charges do not reflect the economic costs of providing services, particularly in comparison with other DCS systems. Charges are based on average costs and AUTODIN subscribers pay for the excess capacity described above.
- For some users, it takes too long to send an AUTODIN message, due to addressing and control procedures, and (for low-precedence messages) due to the time messages spend waiting for available trunks and access lines.

4. Inefficient Allocation of AUTOVON Capacity

AUTOVON capacity is often inadequate to handle the calls AUTOVON users attempt to make (given existing subscriber charges). As discussed in Appendix D, the grade of service (i.e., the probability of failing to complete a call attempt) on the AUTOVON backbone is P14 within CONUS, and as high as P43 between CONUS and Europe. When the chance of encountering busy access lines between the backbone and the intended destination is also considered, the average percent of calls incomplete rises to 40 percent within CONUS.

These conditions lead to a number of sources of waste for DCS users. First, there is the time wasted by users in re-dialing calls. Second, there is a good chance that valuable calls will not be completed at all, or will be delayed so that mission performance suffers. And third, some users will turn to more expensive commercial alternatives or dedicated circuits in order to transact their business, while AUTOVON calls of lower value are getting through (perhaps because less busy users can afford to spend more time re-dialing).

These costs are difficult to measure, but Appendix G outlines an approach to measuring the first type, namely, the cost of time wasted in re-dialing AUTOVON call attempts. Briefly, this method uses the grade of service and the average number of completed calls to estimate the number of blocked call-attempts on the AUTOVON backbone. Assumptions are made as to the amount of time wasted per call attempt, and the value (to the government) of that time. While the estimated dollar value of wasted time is sensitive to which assumptions are made, it is apparent that millions of dollars are involved. For example, assuming that the average blocked call-attempt wastes two minutes and that the time is valued at the 1979 wages of an Army captain, the annual cost of time wasted would be $18,122,000. If the average call attempt takes less than two minutes or if the time involved is worth less than the caller's full wage, then the total cost of wasted time would be less. Appendix G presents cost estimates for a range of assumptions regarding the time wasted per call and the value of that time.

However, if congestion on access lines (rather than just the backbone) is considered, then the number of blocked call-attempts and the cost of time wasted re-dialing is much greater. For example, the average grade of service on the AUTOVON backbone (worldwide) is approximately P16. But the comparable grade of service is approximately P39 when congestion on destination access lines is considered. Using this latter

grade of service, the annual cost of re-dialing is estimated to be $62,670,608 (assuming an average waste of two minutes per blocked call-attempt and evaluating that time at 100 percent of a captain's wage).

There are a number of reasons why the scarce AUTOVON capacity is allocated inefficiently. These reasons include:

- AUTOVON subscriber charges are insensitive to usage, and do not reflect the number and precedence of calls which are made. This reduces incentives within the military departments to control usage administratively.
- Budget incentives are inadequate. Users who decide to place calls do not pay subscriber charges at all. Nor do those who determine the need for access lines typically bear fiscal responsibility for their decisions.
- When circuits are overloaded, routine users have no alternative but to re-dial calls that are blocked.
- Precedence is allocated on the basis of wartime mission requirements. There is no mechanism to permit a subscriber to simply purchase a higher grade of service by paying a higher fee, if he feels his administrative needs warrant it.

5. Provision of Services Using Government-Owned Equipment Is Neither Optimal nor Fully Responsive to User Needs

In overseas areas much of the capital equipment used to provide services is government-owned rather than leased. The equipment is purchased through the procurement budgets of individual military services. Although procurement decisions are jointly planned and coordinated under the DCS Five Year Program, the final result can be less than optimal. This occurs because the agency doing the purchasing tends to take a proprietary interest in its own expenditures and aims first at satisfying its own needs. Subscriber agencies that are not directly involved in a particular procurement decision may need to negotiate with the procuring agency to have their needs satisfied. If there are conflicting objectives, the outcome in

terms of services provided may not be optimal from an overall point of view. The extent to which such decisions are not optimal is difficult to quantify.

6. Summary

This section has discussed five areas in which inefficiency is manifested in the DCS. Further, a number of potential causes have been identified. This information is summarized in Table 3-2, which associates causes with consequences. Thus, by reading down a particular cause column, we can see the manifestations of inefficiency to which that cause contributes. This table illustrates the complex interrelationships among the problems discussed. Each cause induces inefficiency in more than one area, and the manifestations of inefficiency each have multiple causes.

C. CAUSES OF INEFFICIENCY

We have consolidated what we consider to be the causes of inefficiency into three categories: (1) definition, adequacy, and pricing of services; (2) full-cost allocation and subscriber charges; and (3) decentralization of procurement funding. We maintain this categorization throughout the following discussion and attempt to draw the separate threads together and describe the linkages among them at the end of this chapter.

1. Definition, Adequacy, and Pricing of Services

Some of the major sources of DCS inefficiency can be grouped under the general heading of definitions of service, adequacy, and pricing of service. We have organized the discussion around the following topics:

- The insensitivity of subscriber charges to usage.
- Low-quality and inadequate common-user services.
- Subscriber decision-making procedures.

Table 3-2. MANIFESTATIONS OF DCS INEFFICIENCY AND CORRESPONDING CAUSES

Manifestations of Inefficiency	Causes				
	Definition, Adequacy, and Pricing of Services				
	Insensitive Pricing of Particular Systems	Insufficient Variety and Quality of DCS Services	Inadequate Budget Incentives	Failure of Prices to Reflect Full Costs	Decentralized Procurement
Excessive Reliance on Dedicated Circuits	✓	✓	✓	✓	
Failure to Minimize Cost of Providing Dedicated Circuits		✓	✓	✓	✓
Under-Utilized Capacity of AUTODIN	✓	✓		✓	
Waste Associated with AUTOVON Congestion	✓	✓	✓		
Unresponsive Service When Owned Facilities Are Required		✓			✓

The first section describes the consequences of pricing only for access without linking subscriber charges to usage or to actual costs. An important aspect of the analysis is a comparison between the cost of dedicated circuits and the cost of supplying a virtually identical point-to-point service on a common-user network. The second section discusses the effects on user behavior of low-quality or inadequate services on the common-user systems, again with special emphasis on dedicated circuits as the alternative. The final section examines the process whereby the military departments make decisions on how their communications budgets are to be used, including the role that DCS subscriber charges play in that process.

a. Usage-Insensitive Subscriber Charges

The costs of supplying services on a common-user network can be divided into two categories--those associated with giving access to the system and those related to the amount and kinds of services offered and used. To make efficient choices, subscribers should be aware of this division of costs and of the relationship between costs and usage. But subscriber charges offer the only guide users have to the costs of the services they consume. Since the charges do not reflect usage and its associated costs, it is unlikely that subscribers will always make economically correct decisions.

Once hooked up, subscribers determine network costs; that is, they choose whom and when they call, how often to communicate, and how long their messages will be. They make choices with regard to other service characteristics as well, including line-speed, grade of service, waiting time, or message delivery schedule. The cost of establishing, operating, and maintaining a network depends on such customer decisions which determine location, sizing, and design. Further, the services used by each network subscriber are unique, so the costs of serving each subscriber are different. But under the present

pricing structure, large numbers of customers pay the same fee regardless of their usage decisions and the costs associated with those decisions.

Table 3-3 summarizes how DCS subscriber charges are related to service characteristics. As shown, there is no variation in charges with respect to the timing or amount of usage for any network. Individual subscribers to AUTODIN, AUTODIN II, AUTOVON and ATSS pay a monthly access charge which varies somewhat with transmission capability, availability, and community of interest. There are no subscriber charges for ARPANET, WIN, or AUTOSEVOCOM; backbone costs are simply pro-rated among military departments responsible for the various switches. Monthly charges for dedicated circuits (from leases or common-user multiplex systems) depend on the number, transmission capability, distance, and location of circuits ordered.

A number of problems are caused by the usage-insensitive nature of subscriber charges for the common-user switched networks:

- There is no price incentive to control usage.
- There are too few access lines and in some cases their locations are not optimal.
- The choices between alternative communications modes are distorted and too many dedicated circuits are selected.

These problems will now be discussed in turn.

(1) Controlling Usage

Once a subscriber is connected to a DCS network, the charge for using it is zero. Thus, there is no direct price incentive (at any level within the military departments) to control the amount of usage on existing access lines, or to filter out calls which are not worth the costs they impose. For example, subscriber charges provide no information that calls are more

Table 3-3. SUBSCRIBER CHARGE VARIABILITY

Communications System	Service Characteristic				
	Transmission Capability	Availability	Delivery Time	Community of Interest	Timing and Amount of Usage
AUTODIN (Message)	Access charge varies with 3 line-speed categories.	No Variation	No Variation	No Variation	No Variation
AUTODIN (Query/Response)	Access charge varies with 3 line-speed categories.	No Variation	No Variation	Access charge varies with number (up to 6) and location (3 calling areas).	No Variation
ARPANET	No Variation	No Variation	Not applicable	No Variation	No Variation
WIN	No Variation	No Variation	Not applicable	No Variation	No Variation
AUTODIN II	Access charge varies with 8 line-speed categories.	No Variation	Not applicable	No Variation	No Variation
AUTOVON	Access charge higher for data-conditioned trunks.	Access charge varies with 4 precedence levels and with receive-only, send-only, or two-way line direction.	Not applicable	Access charge varies with choice of up to 5 calling area options.	No Variation
AUTOSEVOCOM	No Variation	No Variation	Not applicable	No Variation	No Variation
Alaska TSS	No Variation	No Variation	Not applicable	No Variation	No Variation
Dedicated Circuits (Lease or Multiplex)	Cost varies with choice of line-speed, bandwidth, and conditioning.	Cost varies with grade of service desired.	Not applicable	Cost varies with community of interest inter-connected.	No Variation
Commercial Long Distance	Not applicable	No Variation	Not applicable	Usage charge varies with destination called for toll service; usage charge varies with distance bands for WATS service.	Usage charge varies with number of calls, their duration, time-of-day and time-of-week, for toll service; usage charge varies with number of hours of use (with choice of minimum hours per month), for WATS service.

costly to the government during busy hours or over longer distances within a given calling area.

Access charges provide an indirect incentive to control the amount of usage by giving incentives to control the number of access lines. Also, congestion on access lines provides a non-price incentive for subscribers to control usage. But subscriber agencies usually do not have sufficiently detailed information about calls and callers to manage their access lines efficiently.

(2) Configuring Access Lines

Common-user network costs (to the government) depend on both the number of subscribers and the amount of usage. Since subscribers pay only for access but not for usage, access charges are excessively high, providing a large incentive for subscribers to minimize the number of access lines they acquire. One result is the buildup of private networks connecting to the backbone with a relatively small number of access lines. Another result is congestion due to an insufficient number of access lines, both to place messages and take them off the backbone.

(3) Dedicated vs. Common-User Networks

Before beginning a detailed comparison of dedicated circuits and common-user networks, we shall list some analytical conclusions, keeping in mind that the "costs" we talk about are the costs the government must pay and may not be related to the charges a subscriber faces.

First, it is not possible to generalize about the economic desirability of dedicated circuits relative to common-user networks. Each point-to-point connection has unique characteristics that determine the costs of the two modes, and comparison must recognize those characteristics. Sometimes

dedicated circuits are less expensive and sometimes common-user networks are less expensive. Second, one of the primary determinants of the relative desirability of dedicated circuits is the need for additional access lines for the common-user network. Access lines are a major expense in connecting to the backbone and if no new ones are needed, a dedicated circuit may be a costly alternative to a common-user network. If additional access lines are needed, the dedicated circuit may be less expensive. Third, an inventory of dedicated circuits is needed in order to identify those that could be replaced at less cost by backbone service or to evaluate the total savings that might accrue from replacing dedicated circuits where costs warrant. Fourth, if there is over-reliance on dedicated circuits at present, the primary cause is probably poor pricing policy and inadequate service on the common-user networks rather than perverse or irrational behavior on the part of users.

Dedicated circuits and commercial services are important alternatives to the DCS common-user networks. In some cases, comparable services can be provided at less cost to the government on these alternative systems, and they should be used. In other cases, services could be provided at a lower cost to the government on the DCS switched networks. But because DCS subscriber charges are not equal to the cost of supplying service, subscribers are frequently misled about which is the most efficient method for satisfying their needs and often make the wrong choice.

To illustrate this point we describe the kind of information a subscriber should have in making a choice between a dedicated circuit and similar service on a common-user network, and then compare this to the type of information he actually possesses. We must emphasize that *we are not comparing dedicated circuits to full service on a common-user network*. We

are assuming the subscriber desires only point-to-point service and we examine the costs of alternative ways of supplying it. Full service clearly has advantages and costs that are not considered here.

The important elements that determine the costs of supplying point-to-point service by a dedicated circuit and by a common-user system can be highlighted with a simple model. The model includes the costs of both modes and permits each individual subscriber's situation to be taken into account in determining which is cheaper. Suppose an AUTOVON user has a requirement to communicate between two points, A and B. Within CONUS the points could be linked either directly with a dedicated circuit or indirectly by running an access line from each point into two AUTOVON switches. These alternatives are illustrated in Figure 3-1.

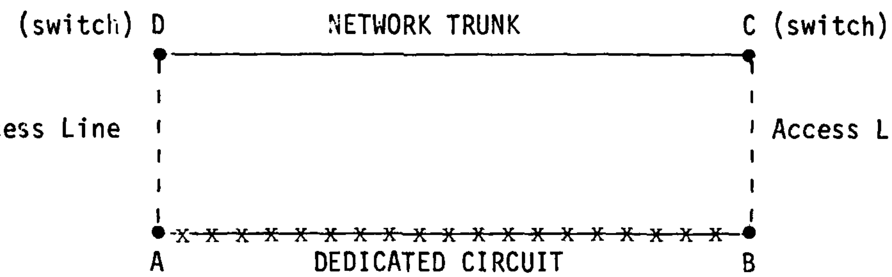

Figure 3-1. CONNECTING A AND B BY DEDICATED CIRCUIT OR COMMON-USER NETWORK

The monthly lease cost of the dedicated circuit would be \$86.60 plus \$0.56 per mile. The monthly cost of connecting through the network would be \$188.25 plus \$0.56 per mile, for each access line; in addition, \$289.90 plus \$0.56 per mile for each new backbone trunk is required to carry the additional

traffic.[1] The total monthly cost for connecting the two points via a common-user network, including leasing an additional network trunk, is $666.40 plus $0.56 per mile, compared to $86.60 plus $0.56 per mile for a dedicated circuit. It is evident that if one must pay full costs on both alternatives, the dedicated circuit always dominates the common-user network in this example.

However, as discussed in Chapter II, the advantage of a network is that trunking costs can be shared among a number of users. If a subscriber occupies his line less than 100 percent of the time, only a portion of a trunk is required to satisfy his requirements. For example, assume that the subscriber expects to use the connection between A and B during the busy hours with a probability of .1 (i.e., he expects to use it for six minutes per hour on average). Then, if the network is already large, it can be expanded to include the new service between A and B by adding approximately .1 trunks, without worsening the grade of service to existing users.[2] (The grade of service between A and B would be P00 on a dedicated circuit. We are explicitly assuming in our cost calculations that the grade of service a subscriber would recieve on the network would be better than P01.) Assuming that two new access lines are required and that each is 86 miles long, the total cost of connecting A and B via the network would be $501.81 plus $.056 per mile for the distance between C and D.[3]

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[1]In addition to the TELPAK charges of $86.60 plus $0.56 per mile, each access line is assessed $75.40 for switch termination and $26.25 for multiple level preemption, and a network trunk is assessed these termination and preemption charges at each end.

[2]We assume here the network is already being used to capacity (with capacity defined in terms of a target GOS) and that any additional traffic will require additional facilities in order to not worsen the grade of service. We discuss the implications of having excess capacity later on.

[3]The $501.81 would include $472.82 for access lines and $28.99 for the increased trunk capacity.

Accepting the assumptions we have made and adding one more, i.e., that the interswitch trunk distance is the same as the distance of the dedicated circuit, it is possible to calculate and compare the costs of providing service between two points over any distance via either a dedicated circuit or the common-user network. Table 3-4 lists those costs under two different assumptions about the degree of usage. The dedicated circuit

Table 3-4. COST COMPARISON BETWEEN DEDICATED CIRCUIT AND AUTOVON (ACCESS LINES REQUIRED)

	Dollars/Month		
Mileage	Dedicated Circuits[a]	Network Routing Probability of Use is .1[b]	Network Routing Probability of Use is .25[c]
100	$ 142.60	$507.41	$559.29
200	198.60	513.01	573.29
300	254.60	518.52	587.29
400	310.60	524.21	601.29
500	366.60	529.81	615.29
600	422.60	535.41	629.29
700	478.60	541.01	643.29
800	544.60	546.61	657.29
900	590.60	552.21	671.29
1,000	646.60	557.81	685.29
1,500	926.60	585.85	755.29
2,000	1,206.60	613.81	825.29

[a]The cost formula for the dedicated circuit is: $86.60 + $.056/mile.

[b]The cost formula for the network with a usage probability of .1 is: $501.81 + $0.56/mile.

[c]The cost formula for the network with a usage probability of .25 is: $545.20 + $0.14/mile. The general cost formula for the network is: $472.82 + P(289.90) + P($0.56)(mileage) where P = probability of use.

is less costly than the network if the distance between the points to be connected is 800 miles or less, and if the probability of use during the busy hours is .1. The actual point of equal cost is 824 miles. When the probability of use is .25, the circuit-sharing advantages of common-user networks are less, so that dedicated circuits are less costly up to a distance of 1,092 miles.

The mileage at which it becomes less costly to use a network than a dedicated circuit consistently increases as the probability of use increases, as shown in Table 3-5. These examples illustrate that the costs of both dedicated circuits and a common-user network *depend importantly on the distance between connected points and the expected utilization rate of the connection during busy hours.*[1]

If accepted at face value, the cost comparisons shown in Table 3-4 are somewhat startling in their implications and run directly counter both to intuition and to the commonly held belief that in a majority of cases dedicated circuits are more costly than a common-user network. Consider, for example, that for any point-to-point distance of less than 824 miles, our calculations indicate that a dedicated circuit is less costly than a common-user network, even if the line is used less than ten percent of the time. Compare this distance with the 230 mile average length of a dedicated circuit. To the extent that this average is representative, our calculations suggest that

[1]The figures for the cost of network routing may understate or overstate the true costs for a number of reasons. First, we assumed an 86 mile access line to a network switch. The location characteristics of dedicated-circuit users may be quite different from those of the average AUTOVON subscribers and average distance from a switch could be either greater or smaller. Second, the average trunk length within AUTOVON is 640 miles. This means that a call that travels further than 640 miles may well pass through more than just the two switches to which the access lines are connected. If this were the case, there would be termination costs that are not included in the figures shown in Table 3-4. These costs would tend to increase the cost of network routing for distances above 640 miles.

Table 3-5. BREAKEVEN MILEAGE BETWEEN DEDICATED CIRCUIT AND COMMON-USER NETWORK

Probability of Use of the Connection	Mileage Above Which Network Routing Is Advantageous
.05	753 miles
.10	824
.20	992
.25	1,092
.30	1,207
.40	1,495
.50	1,897
.60	2,501
.70	3,507
.75	4,312
.80	5,519
.90	11,556

existing dedicated circuits may make economic sense as a way of satisfying point-to-point requirements.

Before accepting the conclusion, however, that the great majority of dedicated circuits indeed represent the most economical way to provide point-to-point or small network service, we must examine further one of the primary assumptions that underlies the previous calculation of the network costs--the assumption that two additional access lines are required in order to connect to the network backbone. This assumption is of major importance because $472.82 of the cost of using the network routing is attributable to the two 86-mile-long access lines. If a subscriber already has an access line into the network on which there is excess capacity, so that *no new access lines are required,* the cost of supplying him with point-to-point service by connecting through the backbone is much less

than the estimates given in Table 3-4. Even if he needs some added access line capacity, but less than a full line, his costs will be below the earlier estimates.[1]

Table 3-6 shows some cost comparisons between dedicated circuits and a common-user network, assuming in one case that no new access lines are needed and in the other that .25 additional access lines are required to provide the service via the network. The implications of the results when no new access lines are required are just as dramatic as they are when a full access line is required for each circuit except that the conclusions are reversed. Without additional access lines, the common-user network is less costly than the dedicated circuit *at any distance* unless the probability of use exceeds .3. If one-quarter of an access line is required at each end of the circuit and the probability of use is .1, the common-user network is less costly than a dedicated circuit at any distance greater than 120 miles. If the probability of use goes up to .25, the cost equalization distance is approximately 250 miles, just 20 miles longer than the current average dedicated circuit.

Table 3-7 indicates the distances at which costs are equal for a dedicated circuit and a common-user network assuming different probabilities of use. Three cases are shown. For one, no new access lines are needed; for the second, one-quarter of an access line is required; for the third, one-half a line is added. The figures demonstrate dramatically the important role the need for new access lines plays in determining whether a dedicated circuit or a common-user network is the cheaper way to satisfy point-to-point communications. They also point out the fact that there are virtually no generalizations one can make about the economic desirability of dedicated circuits

[1]It is, of course, not possible to connect fractions of circuits. If a subscriber wanted ten point-to-point connections, however, it might be possible to satisfy his needs with one access line into the backbone.

Table 3-6. COST COMPARISON BETWEEN DEDICATED CIRCUIT AND COMMON-USER NETWORK (FRACTIONAL ACCESS LINES REQUIRED)

Mileage	Dedicated Circuit[a]	Network Routing			
		No Access Line		.25 Access Lines	
		Probability of Use = .1[b]	Probability of Use = .25[c]	Probability of Use = .1[d]	Probability of Use = .25[e]
100	$ 142.60	$ 34.60	$ 86.50	$152.80	$204.70
200	198.60	40.20	100.50	158.40	218.70
300	254.60	45.80	114.50	164.00	232.70
400	310.60	51.40	128.50	169.60	246.70
500	366.60	57.00	142.50	175.20	260.70
600	422.60	62.60	156.50	180.80	274.70
700	478.60	62.80	170.50	186.40	788.70
800	534.60	73.80	184.50	192.00	302.70
900	590.60	79.40	198.50	197.60	316.70
1000	646.60	85.00	212.50	203.20	330.70
1500	926.60	113.00	282.50	231.20	400.70
2000	1206.60	141.00	352.50	259.20	470.70
AUTOVON SUBSCRIBER CHARGES (excluding access lines)		Routine 305	Priority 610	Immediate 915	Flash 1,220

[a]Cost Formula: $86.60 + $.56/mile.

[b]Cost Formula: $28.99 + $.056/mile.

[c]Cost Formula: $72.48 + $.14/mile

[d]Cost Formula: $147.20 + $.056/mile

[e]Cost Formula: $190.68 + $.14/mile

The general cost formula for the network is: Q($472.82) + P($289.90) + P($.56)(mileage) where Q = fraction of an access line required and P = probability of use.

Table 3-7. MILEAGE AT WHICH COSTS ARE EQUAL FOR A DEDICATED CIRCUIT AND COMMON-USER NETWORK (FRACTIONAL ACCESS LINES)

Probability of Use	Mileage Above Which Network Routing Is Advantageous		
	No Access Line[a]	.25 Access Line[b]	.5 Access Line[c]
.05	0	87	309
.10	0	120	355
.20	0	200	464
.30	0	302	604
.40	87	439	791
.50	208	631	1053
.60	390	918	1445
.70	692	1397	2100
.75	934	1779	2623
.80	1298	2353	3408
.90	3113	5224	7334

Note: The formulae for solving for the breakeven mileages are:

a) $\overline{X} = \frac{517.68P}{1-P} - \frac{154.64}{1-P}$

b) $\overline{X} = \frac{517.68P}{1-P} + \frac{56.44}{1-P}$

c) $\overline{X} = \frac{517.68P}{1-P} + \frac{267.52}{1-P}$

The general formula is:

$$\overline{X} = \frac{844.32Q}{1-P} + \frac{517.68P}{1-P} - \frac{154.64}{1-P}$$

where Q is the fraction of an access line required and P is the probability of use. It is evident the formula is not linear in P.

relative to common-user networks. Each requirement must be evaluated on its own merits.

It has been our intention when the study was initiated to develop, if possible, the data and techniques required to demonstrate the potential cost savings available to DCA from eliminating any given fraction of the total dedicated lines in the

DCS network. We had hoped to be able to provide a table or a function which would permit one to answer the question--"Suppose we shift X percent of the dedicated circuits to a common-user system. How much money could be saved or how much better could service be on the common-user network?" Our analysis has demonstrated, however, that without a complete inventory of the dedicated circuits and their alternatives, developing such a function is impossible. Each circuit is unique in terms of its usage, the distance of its end points from common-user switches and, most importantly, the need the subscriber has for additional access lines to a common-user backbone. Information on all of these characteristics is needed if one is to estimate the potential cost savings.

Thus far we have been concerned solely with the *costs* of supplying point-to-point service and demonstrating how these *costs* vary across subscribers as a function of different characteristics they possess. But at present a subscriber never knows what these costs are. He has no opportunity to make the kind of comparison we have made between a common-user network and dedicated circuits because his alternatives consist of a dedicated circuit on the one hand and access to the entire common-user network on the other. The cost comparison he must make is equally gross. The prices he pays for dedicated circuits are those we have shown in Tables 3-4 and 3-6 and depend upon distance. The common-user network charges are fixed and independent of the subscriber's circumstances and of the services he actually requires.

In the earlier discussion and tables we compared the costs of supplying one kind of service (point-to-point with high GOS) through two different modes (common-user and dedicated networks). Since the service now offered on AUTOVON is not identical to a dedicated circuit, we cannot make a similar comparison between subscriber charges. What we can do, however, is assume the

subscriber has a budget and compare the kinds and amounts of service he might receive from spending a given number of dollars on either access lines to a common-user network or dedicated circuits.

Tables 3-8 and 3-9 show the subscriber costs of interconnecting from two to twenty communication points by either common-user networks or dedicated circuits. Table 3-8 refers to AUTOVON and Table 3-9 to AUTODIN I and II. In looking at Table 3-8, for example, we see that a routine subscriber with five communication points would pay $2,725 per month for five AUTOVON access lines. Alternatively, for the same or less outlay he could connect the five points with ten dedicated circuits as long as the average circuit length was no more than 325 miles. The grade of service on the dedicated lines would be P00, however, or the equivalent of Flash. If the subscriber were willing to pay for Flash, his hypothetical budget for connecting the five points would be $7,300 and he would prefer dedicated circuits as long as their average length did not exceed 1,130 miles.[1] Similar comparisons can be made for AUTODIN I and II. All of these calculations assume that a new access line is required for each communication point. If no new access lines are required, the costs of interconnecting by means of common-user networks are considerably less.

Given the present pricing system, dedicated circuits have a price advantage for subscribers relative to common-user systems in certain situations. This advantage holds particularly for small communities of interest, and over relatively short distances, and is due to the fact that subscriber charges for common-user networks are fixed and do not reflect actual usage or actual costs.

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[1] Interconnection by means of dedicated circuits could be even less expensive if users were connected in series on multi-point lines or if simple switching arrangements were introduced.

Table 3-8. TRADEOFFS BETWEEN DEDICATED VOICE CIRCUITS AND AUTOVON ACCESS IN CONUS

Number of Users	Number of Dedicated Circuits to Interconnect[a]	ROUTINE Charges for Routine AUTOVON Service[b] (Dollars): Subscriber Charge	+ Access Line	= Total	Average Length of Dedicated Circuits[c] (Miles)	FLASH Charges for Flash AUTOVON Service[b] (Dollars): Subscriber Charge	+ Access Line	= Total	Average Length of Dedicated Circuits[c] (Miles)
1	-	305	+ 240	= 545	-	1,220	+ 240	= 1,460	-
2	1	610	+ 480	= 1,090	1,764	2,440	+ 480	= 2,920	4,986
3	3	915	+ 720	= 1,635	805	3,660	+ 720	= 4,380	2,416
5	10	1,525	+ 1,200	= 2,725	325	6,100	+ 1,200	= 7,300	1,130
10	45	3,050	+ 2,400	= 5,450	58	12,200	+ 2,400	= 14,600	416
15	105	4,575	+ 3,600	= 8,175	0	18,300	+ 3,600	= 21,900	212
20	190	6,100	+ 4,800	= 10,900	0	24,400	+ 4,800	= 29,200	116

[a]The number of circuits necessary to interconnect all users directly is $\frac{n(n-1)}{2}$.

[b]Charges for each user include subscriber charges and the cost of leasing an access line (namely the TELPAK channel and termination charges, AUTOVON switch termination charges, line pre-emption charges, and DECCO-overhead charges for a voice line of average length (i.e., 86 miles)).

[c]If AUTOVON charges were instead used to interconnect users by dedicated circuits, this is the average length of circuit which could be leased.

Table 3-9. TRADEOFFS BETWEEN DEDICATED DATA CIRCUITS AND AUTODIN ACCESS IN CONUS

Number of Users	Number of Dedicated Circuits to Interconnect[a]	TELETYPE Charges for AUTODIN Teletype Service[b] (Dollars): Subscriber Charge	+ Access Line	= Total	Average Length of Dedicated Circuits[c] (Miles)	WIDEBAND Charges for AUTODIN II 56,000 b.p.s. Service[b] (Dollars): Subscriber Charge	+ Access Line	= Total	Average Length of Dedicated Circuits[c] (Miles)
1	-	1,425	+ 146	= 1,571	-	5,368	+ 3,104	= 8,472	-
2	1	2,850	+ 292	= 3,142	10,754	10,736	+ 6,208	= 16,944	2,298
3	3	4,275	+ 438	= 4,713	5,222	16,104	+ 9,312	= 25,416	1,056
5	10	7,125	+ 730	= 7,855	2,456	26,840	+ 15,520	= 42,360	435
10	45	14,250	+ 1,460	= 15,710	920	53,860	+ 31,040	= 84,720	90
15	105	21,375	+ 2,190	= 23,565	481	80,520	+ 46,560	= 127,080	0
20	190	28,500	+ 2,920	= 31,420	273	107,360	+ 62,080	= 169,440	0

[a]The number of circuits necessary to interconnect all users directly is $\frac{n(n-1)}{2}$.

[b]Charges for each user include subscriber charges and the cost of leasing an access line (namely the TELPAK channel and termination charges, and DECCO overhead charges, for a circuit of average length (i.e., 206 miles for teletype and 269 miles for 56,000 bps)).

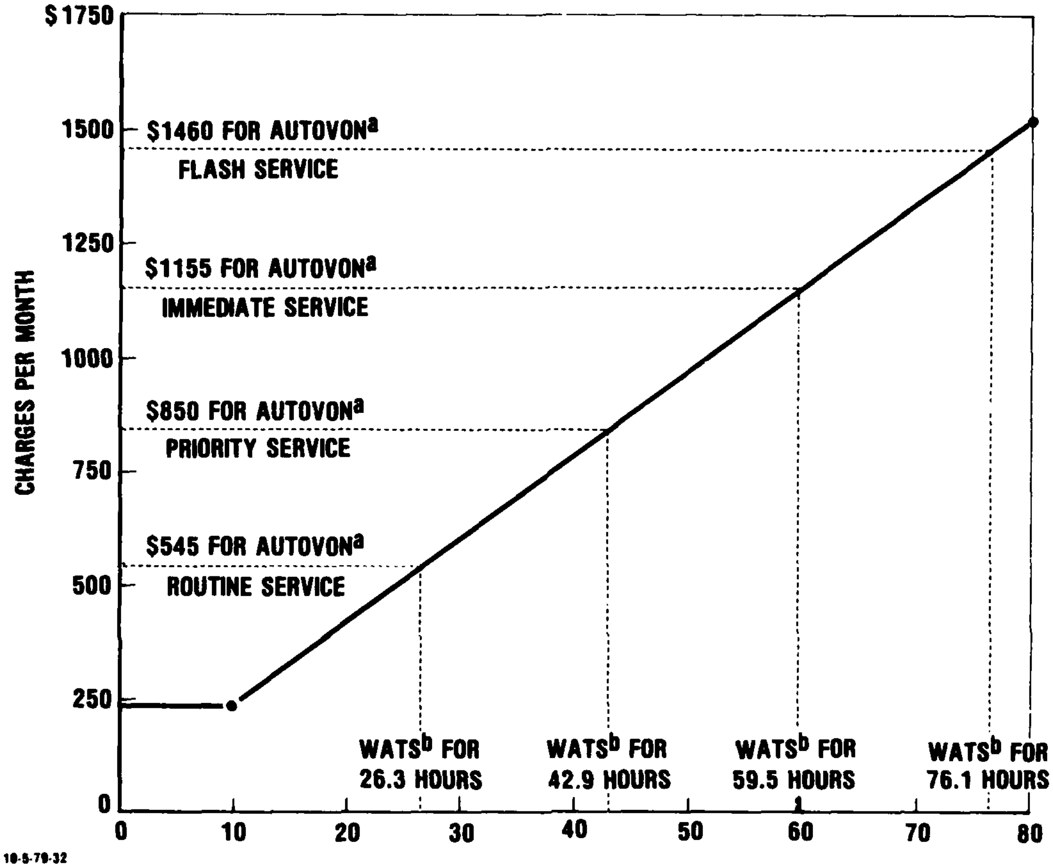
[c]If AUTODIN charges were instead used to interconnect users by dedicated circuits, this is the average length of circuit which could be leased.

There are two rather important observations that should be made before we leave the topic of dedicated networks and the costs (both to suppliers and subscribers) of alternatives. First, if one compares the *actual cost* in Table 3-4 of supplying a 400-mile point-to-point connection on a common-user network to a user with .1 probability of use (about $524), to the *access charges* shown in Table 3-8 that a subscriber must pay for subscriber charges and two average length access lines into AUTOVON ($1,090), one finds that the access charges are about twice the actual cost of providing the service.

Second, according to Tables 3-8 and 3-9, based on current price structure, the cost advantage to the subscriber of dedicated circuits appears to be large when the number of points rises. From an overall efficiency point of view, however, the Table is misleading. The proper comparison should be based on government costs, similar to Tables 3-4 and 3-6. The cost of each dedicated circuit or dedicated network should be compared to the cost of the specific common-user alternative to arrive at a proper decision as to which is the most economic mode to select.

(4) Commercial Alternatives

Commercial long-distance service also offers price advantages to subscribers in certain situations. Figure 3-2 indicates the number of hours of WATS service that could be purchased for the price of AUTOVON access at each of four precedence levels. For example, an immediate subscriber requiring less than 58 hours of long-distance calls per month within CONUS would find WATS service cheaper than AUTOVON. On AUTOVON, a subscriber is forced to pay for the average amount of usage, even when his own usage is much less than average. On WATS he can select and pay for the amount of service he expects to actually use. As with dedicated circuits, however, the proper



Hours of WATS Service Per Month which could be purchased for Respective AUTOVON Subscriber Charge.

[a]FY80 AUTOVON Subscriber Charge plus $240 for leased access-line charges.

[b]WATS charges in Virginia are $245 per month plus $18.38 for each hour of use exceeding 10 hours per month, for calls to 47 other states.

WATS SERVICE AND AUTOVON SUBSCRIBER CHARGES

comparison should be between *actual costs* on AUTOVON and the price of WATS service. The comparison would be easy to make if AUTOVON provided a service like WATS, with subscriber charges based on costs.

b. Inadequate Common-User Services

The services offered on the DCS common-user switched systems are often of low quality or are inadequate in other respects. These difficulties lead some subscribers to select dedicated circuits, even in cases where higher quality services could in principle be provided at less cost to the government on common-user systems. In addition, these problems lead to inefficient use of existing common-user capacity. The major problems are:

- Availability (grade of service) for AUTOVON
- Allocation of circuits for AUTOVON
- Transmission capability (line-speed) for AUTOVON
- Delivery time (line-speed and speed of service) for AUTODIN
- Availability and line-speed for AUTODIN II.

(1) Availability for AUTOVON

Availability of service for AUTOVON is defined as the grade of service, which is the probability that a call attempt will be blocked within the backbone. For certain communications applications, a grade of service of P00 is required. That is, no positive probability of blocking is acceptable. These applications include command-and-control functions and certain real-time control and signaling systems.

The AUTOVON backbone trunking and preemption capabilities are designed to provide nearly a P00 grade of service on the backbone to flash users, even during emergency periods. But a significant problem is how credible such a non-blocking

guarantee can be. A military commander may require non-blocking not only on the backbone but on the access lines as well. Whether the flash service is truly non-blocking depends not only on how well AUTOVON has anticipated the needs of all flash users but also on access line configuration and use. A destination access line could be occupied by another flash call. Thus, a commander might want the reassurance of a dedicated circuit.

For non-flash (and especially for routine) subscribers, the grade of service on AUTOVON can be quite poor during non-emergency periods, and potentially much worse during future emergency periods. This can result in wasted time, personal frustration, and degraded mission performance.

To some extent, blocked AUTOVON calls lead to the use of more expensive alternatives, including commercial toll calls and dedicated circuits. Such alternative services provide safety valves, enabling defense organizations to perform their missions despite the poor service on AUTOVON. But turning to those alternatives may be inefficient, when a better grade of service could be provided on AUTOVON at a lower cost to the government. Use of those alternatives could also be viewed as circumvention of OSD and JCS budget philosophy. That is, OSD and JCS priorities do not permit funding AUTOVON to provide good service to administrative users. But those same users may then obtain funding for good service on dedicated circuits or from commercial alternatives.

Poor AUTOVON grade of service is due to a lack of funds not only for the AUTOVON backbone, but also for subscriber access lines. The shortage of access lines leads to a further degradation of service on both backbone and access lines; that is, a substantial part of the time, access lines and backbone trunks are occupied by call attempts to destination access lines which are occupied by similar attempts. To add an access line, a subscriber must pay the full backbone charge, plus the cost of

an access circuit. These large incremental costs dissuade many subscribers from ordering an adequate number of lines.

(2) Allocation of Circuits for AUTOVON

Given the current structure of user fees, there is a shortage of AUTOVON capacity.[1] Inevitably this means that a substantial number of call attempts will not be completed. Which calls are completed is determined partially by the precedence system, and largely by chance. Because higher precedence call attempts can preempt trunks occupied by calls of lower precedence, there is some assurance that the more important calls will go through. But the maximum precedence authorized for particular access lines is based on command-and-control criteria. There is little to prevent users of those access lines from claiming precedence for administrative call attempts, and thus competing unfairly with callers using routine access lines. Further, AUTOVON trunks and access lines are assigned randomly to the first routine caller requesting the line when it becomes free. No preferential treatment is given to the caller who has waited the longest, or to the routine call attempt which is the most important. Almost 98 percent of CONUS AUTOVON calls are routine, and those calls surely encompass a wide range of values. Hence, the random assignment of AUTOVON trunks and access lines potentially results in a serious misallocation of AUTOVON capacity. It should not be surprising if the more important routine users seek alternative services.

(3) Transmission Capability for AUTOVON

AUTOVON voice circuits can be used to transmit digital information at a rate of up to 2,400 bits per second (bps).

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[1]Even if charges were to be made sensitive to usage, there might still be inadequate capacity. But until prices are made economically correct, it is difficult to determine whether capacity is wrong or not. See IDA Study S-504 for a more complete discussion of this point.

But the conditioning of AUTOVON trunks is generally inadequate for transmission of higher bit rates at acceptable levels of transmission error. Thus, AUTOVON cannot be used for many high-speed computer applications. Further, the use of AUTOVON trunks for secure-voice calls (which are transmitted as digital information) results in low-quality reception. Since bad reception can lead to misunderstanding of critical information, secure-voice users often turn to dedicated circuits to meet their needs.

A few data-conditioned AUTOVON trunks are available overseas. These permit transmission at 4,800 bps, or at 9,600 bps if only a single circuit segment is involved. AUTOVON formerly offered data-conditioned circuits in CONUS, but that service was eliminated due to difficulties in integrating the voice- and data-conditioned trunks into the same network.

(4) Delivery Time for AUTODIN

AUTODIN messages are stored at backbone switches and then dispatched as appropriate trunks become available. The process of switching messages from trunk to trunk is time-consuming, and waiting time at the switches can be substantial when network trunks are congested. In addition, the system is not designed to meet real-time signaling requirements. In part, the precedence system assures that the most important command-and-control messages receive preferential treatment. But any subscriber can claim up to flash precedence. This, together with uncertainties regarding the adequacy of AUTODIN trunking during emergency periods, could cause a commander to seek the reassurance of a dedicated circuit for his critical wartime messages.

Although AUTODIN access lines may have transmission capabilities of up to 4,800 bits per second, switching and storage delays on the backbone reduce the effective end-to-end line-speed far below that rate. Thus, AUTODIN is not suitable for

many high-speed computer applications. Guaranteed Sequential Delivery and Query/Response are important improvements in AUTODIN service, but they cannot substitute for high transmission line-speed.

(5) Availability and Line-Speed for AUTODIN II

Because packet-switching networks cannot tolerate backbone congestion, the rate at which AUTODIN II subscribers transfer information to the backbone will be closely controlled at the AUTODIN II switch. During busy periods, the network will reduce the effective line-speed at which subscribers transmit, and may force subscribers to wait before transmission can begin. Thus, even though AUTODIN II is an important advance, providing the higher line-speeds not available on AUTOVON or AUTODIN, it will not provide service fully equivalent to a subscriber's own dedicated circuit.

c. Subscriber Decision-Making Procedures

The military departments have difficult tasks in deciding how best to spend their limited communications budgets. How well they are organized internally to make these decisions has a major bearing on the overall efficiency of defense communications.

The basic problem, as in many other bureauracies, is that the responsibility for decisions is divided between two or more distinct groups of people. Users (i.e., agencies whose missions are supported by communications services) know the contributions that different services can make to mission performance, and so they decide what they need. But communications commands (and to some extent department headquarters staffs) know how much budget money is available for communications, and so they decide whose needs are satisfied.

Because communications users typically do not have their own communications budgets, they have little incentive to exercise fiscal responsibility when making communications choices; for example, the individual who decides whether to send a particular message or make a particular call. He does not pay for the service, and has no reason to question whether his use is cost-effective. The individual who decides what communications services need to be provided to accomplish his mission is in a similar position.

A lack of fiscal responsibility at the point where needs are determined can have serious consequences which are difficult to correct at later stages. The efficient user would consider the contributions different services could make to mission performance, and compare them to the costs to the government of the different types of services. Without fiscal responsibility, the user has little incentive to take government costs into account when defining his needs.

In an attempt to assure that costs are considered, the military departments employ elaborate validation procedures, to verify that users need the services they request, and that least-cost methods are selected for satisfying those needs. The level at which requests must be approved increases with the cost of a request. Undoubtedly, these validation processes accomplish some good, but they suffer from the fact that it is difficult for any outsider to evaluate a particular user's needs, and from the lack of fiscal responsibility on the part of the participants. As a result, validation is often strictly *pro forma*, and requirements are approved which are not cost-effective.

Communications commands and department headquarters staffs decide which of the approved requirements are satisfied from the limited communications budgets. Because requirements usually exceed available funds, especially in recent years, these

staffs have clear incentives to satisfy the most important requirements at least cost. But they are hampered in their efforts by the difficulty of determining from the outside how important a requirement is. Nor is it easy to change the method of satisfying a requirement once the requirement has been approved.

Nevertheless, communications commands are able to influence communications efficiency in several ways. Those requirements which cost enough to necessitate approval at the military department headquarters level are usually subject to evaluation by the communications commands prior to approval. In addition, field elements of the communications commands frequently assist users in defining their requirements. This is particularly important for DCS requirements since the DCS provides transmission service only, and requirements must be defined in technical terms.

While communications commands typically include all user requests in their budget submissions, available funds are less than those submissions, so some requests must be turned down. Priorities for satisfying requirements are established partially at department headquarters, but communications commands have considerable latitude in deciding whose requirements are funded. Thus, the communications commands are sometimes able to coax users into trying low-cost methods, or to force them to trade an existing service for a new one. If the communications command cannot fund a requirement, the user may re-program funds from his own budget in order to satisfy it. Also, the Air Force has initiated a program to allocate blocks of funds to major commands, allowing them to decide the best way to spend them (for non-common-user, long-haul requirements). Such a step is a response to the general problem that communications commands are not in a position to determine the value of various requirements, and hence cannot themselves decide which requirements should not be funded.

In summary, while military departments do respond to budgetary pressures, and to price incentives provided by DCS subscriber charges, their decisions on what services to order will not always be efficient.

2. Failure of Subscriber Charges to Reflect Full Costs

In the sections above we have discussed a number of problems that are created when the prices users pay are not related to the costs they impose when using the system. In addition to the distortions created by the absence of usage-sensitive pricing, further distortions result from the fact that a large portion of the costs are omitted altogether in calculating the prices users pay for services.

The total cost of providing a service is the cost of all resources used in the production of the service, even though some resources may be owned. The capital cost of owned equipment is often viewed as "sunk cost" by the DoD and virtually ignored in decision-making processes. But the owned resource (or the money used to purchase the asset) has an alternative use and this resource cost should be included as part of total production cost. Total economic costs thus include:

- Lease Costs: Equipment and services leased from common carriers represent resources used in providing a service. The price of a service provided entirely by leases (such as a leased dedicated circuit) will come close to reflecting the total economic cost since the charge to the customer is made up of the lease cost plus a one and one-half percent DECCO (overhead) charge. The lease cost reflects the common carrier's cost of providing the circuit, including capital, overhead, operating and maintenance costs.
- User Cost of Capital Stock: The cost of capital stock (equipment and buildings and roads, etc.) per period which should be included in the total production cost per period would be the amount of depreciation of the capital stock--the amount of capital stock that is being "used up" by the current period's production.

This amount can also be viewed as the flow of funds necessary to maintain the capital stock at the existing level.

- Operation and Maintenance Costs: The cost of operating and maintaining the communications system includes the cost of transmission, switch, and other equipment. The cost of military manpower used to operate or maintain equipment should also be included.
- Overhead Cost of Managing System: The cost of providing a service includes the cost of engineering the systems and the cost of personnel used in helping users choose services. For the DCS, this overhead cost includes the cost of operating DCA headquarters and subsidiary offices, cost of engineering and installing equipment and systems, and part of the cost of operating communications commands of military departments.
- Research and Development Cost: The cost of research and development can be viewed as investment to provide future services. It can thus be treated the same way as capital is treated. The current cost of R&D is really a portion of the R&D costs incurred in previous years. When possible, research and development expenditures should be allocated to the specific system or equipment the expenditure supports. For example, research and development cost for satellites should be allocated to satellite transmission.
- Land: The cost of land (owned or leased) used for communications equipment is an economic cost of production and in principle should be included. However, this cost is not included in our estimates.
- Financing Costs: In the private sector there is a cost to borrowing capital that is the return that the capital must earn. Strictly speaking this cost still exists even though the funds are raised through taxes. We do not include this cost in our calculations, however, except to the extent that it is included in the fee paid commercial carriers for leased equipment.

In general, customers of DCS services pay for only part of the costs listed above. Those they do not pay for include: (1) depreciation on government-owned equipment; (2) costs of operating and maintaining transmission equipment; (3) military personnel cost of operating and maintaining switches; (4) overhead cost of managing systems (excluding DECCO); and

(5) research and development costs. Not all systems are treated equally, however, with respect to the amount and proportion of costs that are ignored in setting the prices charged for their services. The most important division is that between services supplied on leased equipment and those supplied on government-owned equipment.

Since a common carrier must pay for all the resources it uses, the fee paid by the Communications Services Industrial Fund (CSIF) for leased equipment normally reflects the total cost of providing a circuit. On the other hand, the CSIF does not pay for most of the items listed above when services are supplied on government-owned equipment. Since charges for DCS services are based on CSIF costs, prices for DCS services which use primarily leased equipment will usually be higher to the user than prices of services supplied on government-owned equipment. This price distortion may cause customers to make inefficient choices not only among DCS services but also between DCS and commercial services. In the following sections we try to evaluate the extent to which price distortion exists and estimate its impact on subscriber budgets.

The specific steps include:

- Estimating the real cost to government of providing various services during FY78. This involves measuring the total cost of the DCS for FY78 and allocating the cost to the different systems.
- Comparing the current prices (cost to users) with the full cost (to government) of providing the services.
- Evaluating how full-cost pricing might affect the budgets of the military departments.

a. Allocation of Cost to DCS System

The prime determinant of whether or not a majority of the cost of a DCS service is included in the price charged for it is the proportion of the capital equipment used in producing the service that is government-owned rather than leased.

Typically, both depreciation and O&M costs related to government-owned equipment are excluded from subscriber charges. In turn, the main factor influencing a lease or buy decision is geography. In the United States, most equipment and services are leased, while overseas, most equipment is government-owned, in part due to a lack of adequate commercial facilities in many countries. Thus, in attempting to evaluate the degree to which prices understate true costs, a logical categorization is geographic. In what follows, we attempt to compare the total costs of producing the services provided by the three major components of the DCS, AUTOVON, AUTODIN and dedicated circuits, to the costs that are included in determining their prices in each of the major geographic areas.

Allocating costs to the individual systems is not an easy task since many resources are shared by more than one system. To do so with accuracy would require information on how each piece of equipment or circuit is used and what share of its capacity should be allocated to each of the systems that occupy it. Examining the data at this level of detail was beyond the scope of this report, however, and what we present are some rough estimates of the costs of different systems by geographic area.

The Circuit and Trunk file, the DCS Capital Cost Model, the DCS Operating and Manpower Report II, and the CSIF Budget were the primary data sources for this estimation.[1] In general, the costs of capital assets (leased and owned) and the cost of operating and maintaining transmission equipment are available by geographic area. These costs were allocated to a particular system according to the system's share of the total number of circuits in the area, where the numbers of circuits are

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[1]The reader may refer to Appendix H for further discussion on how the cost allocation was carried out.

adjusted for variations in circuit length and cost.[1] The cost of switch equipment was allocated directly to the system it supports. Research and development costs for satellite transmission were allocated to satellite circuits. Other research and development costs and DCA overhead costs were allocated to a DCS system and area in the same proportion as the system's (and area's) share of total transmission and switch costs. This method of allocating costs is somewhat arbitrary since we have no information on the degree to which the system actually makes use of the shared equipment, but the resulting estimates give us a general impression of how relative prices would be affected if all economic costs were "counted."

The estimated total costs of the various DCS services for 1978 are presented in Table 3-10. Especially striking is the magnitude of the cost of dedicated lines compared to the cost of AUTOVON and AUTODIN. Total costs were $195,743,000 for AUTOVON and $58,859,000 for AUTODIN. The cost of dedicated lines was about two and one-half times that of *both* AUTOVON and AUTODIN at $632,088,000. This relationship between total costs for dedicated circuits and the common-user networks contrasts markedly with the relationship between CSIF lease costs for dedicated and common-user systems. If the comparison is made in these terms, dedicated circuit costs amount to only 42 percent of combined costs on AUTOVON and AUTODIN. Looking at total costs indicates that dedicated circuits are a much more significant problem than annual DCS budgets would imply.

The absolute magnitudes of total expenses of dedicated circuits are revealing, but of equal interest are some estimates of ratios of prices charged to the full costs of supplying the corresponding services. According to our estimates, the ratio in CONUS of price to full cost is significantly less

[1]The results using numbers of circuits unadjusted for circuit mileage are virtually the same as the results reported here.

Table 3-10. ESTIMATED TOTAL ANNUAL COST OF DCS SERVICES IN FY78 ($000)

	CONUS[a]	EUROPE	PACIFIC	CON-EUR	CON-PAC	CON-CARIB	CARIB	ALL AREAS
AUTOVON								
Owned Transmission (excl. Sat.)[b]	--	12,283	4,395	--	--	--	--	16,678
Satellite Transmission[c]	2,156	15,090	12,676	4,225	5,777	1,207	--	41,131
Leases (incl. DECCO)	61,519[d]	1,147[d]	12,151[d]	6,794[d]	4,043[d]	1,251[d]	--	86,905[d]
Owned Switches[c]		4,417	2,217	--	--	--	442	7,076
Switch O&M	--	1,017[d]	407[d]	--	--	--	102[d]	1,526[d]
Overhead and R&D	13,103	11,613	10,329	3,028	3,507	781	66	42,427
TOTAL	76,778	45,567	42,175	14,047	13,327	3,239	610	195,743
% of Total Cost Included in Subscriber Charge	(80)	(5)	(30)	(48)	(30)	(39)	(17)	(45)
AUTODIN								
Owned Transmisison (excl. Sat.)[b]	--	1,670	950	--	--	--	--	2,620
Leases (incl. DECCO)	33,653[d]	1,050[d]	7,640[d]	581[d]	422[d]	--	--	43,346[d]
Owned ASC's[c]	--	1,507	2,315	--	--	--	--	3,822
Overhead and R&D	6,467	691	1,792	70	51	--	--	9,071
TOTAL	40,120	4,918	12,697	651	473	--	--	58,859
% of Total Cost Included in Subscriber Charge	(84)[e]	(21)[e]	(60)[e]	(89)[e]	(89)[e]	--	--	(74)[e]
DEDICATED CIRCUITS								
Owned Transmission (excl. Sat.)[b]	99,700	108,668	90,530	--	--	--	--	298,898
Satellite Transmission[c]	23,627	32,250	45,616	14,918	13,711	8,451	--	138,573
Leases (incl. DECCO)	35,727[d]	5,183[d]	5,387[d]	5,049[d]	2,874[d]	1,432[d]	--	55,652[d]
Overhead and R&D	40,064	36,798	41,595	8,406	7,51[illegible]	4,590	--	138,965
TOTAL	199,118	18[illegible],839	183,128	28,373	24,097	14,473	--	632,088
% of Total Cost Included in Subscriber Charge	(18)	(3)	(3)	(18)	(12)	(10)	--	(9)
AUTOVON ACCESS LINES								
Owned Transmission (excl. Sat.)[b]	--	10,316	5,725	--	--	--	--	16,041
Leases (incl. DECCO)	38,768[d]	223[d]	789[d]	--	--	--	--	39,780[d]
Overhead and R&D	7,450	1,722	1,070	--	--	--	--	10,242
TOTAL	46,218	12,261	7,584	--	--	--	--	66,063
% of Total Cost Paid by Subscriber	(84)	(2)	(10)	--	--	--	--	(60)
AUTODIN ACCESS LINES								
Owned Transmission (excl. Sat.)[b]	1,179	3,818	2,526	--	--	--	--	7,523
Leases (incl. DECCO	1,898[d]	186[d]	497[d]	--	--	--	--	2,581[d]
Overhead and R&D	591	654	497	--	--	--	--	1,742
TOTAL	3,668	4,658	3,520	--	--	--	--	11,846
% of Total Cost Paid by Subscriber	(52)	(11)	(14)	--	--	--	--	(22)

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ECONOMIC EFFICIENCY IN THE MANAGEMENT OF DCS SEPVICES.(U)

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Table 3-10. (Cont'd)

	CONUS[a]	EUROPE	PACIFIC	CON-EUR	CON-PAC	CON-CARIB	CARIB	ALL AREAS
AUTOSEVOCOM								
Owned Transmission (excl. Sat.)[b]	--	85	222	--	--	--	--	307
Owned Switches	316	190	151	--	--	--	--	657
Overhead and R&D	61	45	61	--	--	--	--	167
TOTAL	377	320	434	--	--	--	--	1,131
% of Total Cost Included in Subscriber Charge	(0)	(0)	(0)	--	--	--	--	(0)
AUTOSEVOCOM ACCESS LINES								
Owned Transmission (excl. Sat.)[b]	2,559	6,424	5,132	--	--	--	--	14,115
Overhead and R&D	491	1,050	843	--	--	--	--	2,384
TOTAL	3,050	7,474	5,975	--	--	--	--	16,499
% of Total Cost Paid by Subscriber	(0)	(0)	(0)	--	--	--	--	(0)
ARPANET								
Leases (incl. DECCO)	3,738[d]	--	--	--	--	--	--	3,738
Overhead and R&D	718	--	--	--	--	--	--	718
TOTAL	4,456	--	--	--	--	--	--	4,456
% of Total Cost Included in Subscriber Charge	(84)	--	--	--	--	--	--	(84)
ATSS								
Leases (incl. DECCO)	5,096[d]	--	--	--	--	--	--	5,096[d]
Overhead and R&D	979	--	--	--	--	--	--	979
TOTAL	6,075	--	--	--	--	--	--	6,075
% of Total Cost Included in Subscriber Charge	(84)	--	--	--	--	--	--	(84)
TOTAL COST OF ALL DCS SERVICES								992,760

[a]This column also includes costs for facilities within the western hemisphere but outside the continental United States.

[b]Includes depreciation and O&M.

[c]Includes depreciation only.

[d]Included in subscriber or lease charges.

[e]While the same AUTODIN Subscriber Charge applies to all areas, these figures suggest the extent of distortion by area.

for dedicated circuits than it is for AUTOVON and AUTODIN. Users of dedi ated circuits on average pay 18 percent of full government cost, while users of AUTOVON and AUTODIN pay 80 percent and 74 percent of full cost, respectively. This subsidy is not available to everyone because many dedicated circuits are leased from commercial carriers. Users of leased dedicated circuits pay close to the full cost of a dedicated circuit while users of government-owned circuits pay much less than the 18 percent (or nothing at all). Thus, the 18 percent figure does not reflect the amount a typical user of dedicated circuits pays--it is simply the mean amount paid across all users. When the subsidy is available, it gives subscribers a large incentive to purchase dedicated circuits when the efficient choice might be the use of AUTOVON or AUTODIN.

In Europe, as in CONUS, users of dedicated circuits on average pay a smaller proportion of the full cost of the service (3 percent) than do subscribers to AUTOVON (5 percent) and AUTODIN (74 percent). The comparison between dedicated circuits and AUTODIN is particularly striking. A cost-conscious subscriber with a small community of interest in Europe would almost certainly find dedicated circuits more attractive than AUTODIN. Similar relationships between costs and prices exist for all geographic areas. On average, worldwide AUTOVON prices are 45 percent of costs, AUTODIN prices are 74 percent, and dedicated circuit prices are 9 percent of costs. The price distortion resulting from the failure to account for full cost in subscriber charges gives users incentives to purchase dedicated circuits instead of common-user switched services. Further, since the price for these services is lower than the full cost to the government, users may purchase more of all of them.

These figures permit some rough estimates of the tradeoffs that might be made between expenditures on dedicated circuits and the grade of service on AUTOVON. It has been estimated

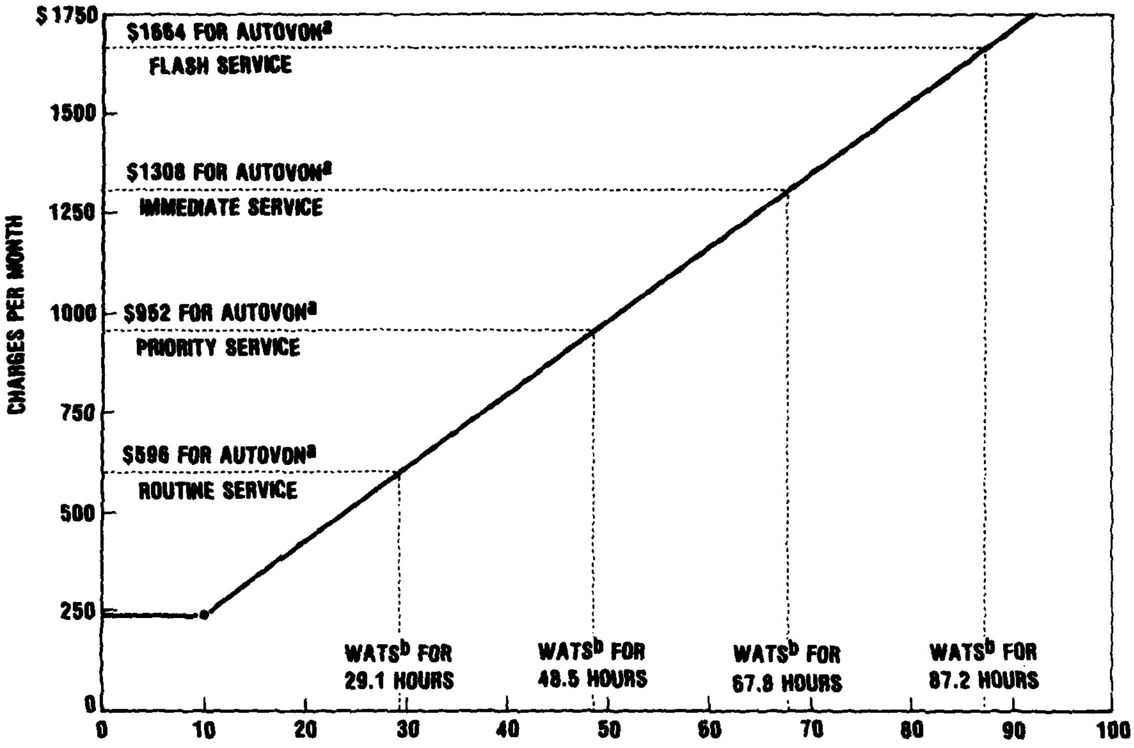
by DCA that it costs approximately $650,000 to improve the grade of service on AUTOVON in CONUS by one point. A one percent reduction in the cost of dedicated circuits (excluding access lines) in CONUS alone would amount to $1,991,000. If this amount were applied to increase the number of leased AUTOVON trunks in CONUS, grade of service would be improved by three points.

Also, as shown in the second part of Table 3-10, there are large differences among CONUS, Europe and the Pacific in the fraction of AUTOVON and AUTODIN access line costs which subscribers must pay. In Europe, AUTOVON access lines are virtually free, while subscribers pay ten percent of costs in the Pacific and 84 percent of costs in CONUS.

b. Effect of Full-Cost Pricing on Subscriber Charges

If full-cost pricing were adopted, the subscriber charges paid for the common-user switched systems and for dedicated circuits would increase. Table 3-11 contains estimates of what full-cost prices per weighted unit would have been for AUTOVON and AUTODIN as well as what the FY78 billing rates actually were. In some instances there are large differences. For example, the FY78 billing rate for Europe was $65 per month per weighted unit, as compared to a full cost of $1,156.

These average full-cost charges can also be compared with the price of WATS in CONUS. Figure 3-3 indicates the number of hours of WATS service that could be purchased for the full-cost AUTOVON subscriber charges. For example, an immediate subscriber would pay $1,350 for an AUTOVON connection. If he required less than 67 hours of long-distance calls per month, WATS service would be cheaper than AUTOVON.



Hours of WATS service per month which could be purchased for respective AUTOVON (full-cost) subscriber charge.

[a]Full-cost AUTOVON monthly rate (see Table 3-11) plus $240 for leased access-line charges.

[b]WATS charges in Virginia at $245 per month plus $18.38 for each hour of use exceeding 10 hours per month, for calls to 47 other states.

Figure 3-3. WATS SERVICE AND AUTOVON (FULL-COST) SUBSCRIBER CHARGES

Table 3-11. CURRENT AND FULL-COST CHARGES FOR AUTOVON AND AUTODIN

	Actual FY78 Monthly Charge Per Weighted Unit	Estimated Full-Cost Monthly Charge Per Weighted Unit[a]
AUTOVON		
Area		
CONUS	253	356
Europe	35	1,156
Pacific	340	1,256
Area +		
CONUS-Europe	591	2,154
CONUS-Pacific	799	2,129
CONUS-Caribbean	358	612
Global	1,242	4,813
AUTODIN	650	707.68

[a]These estimates are based on the access lines in being as of April, 1979.

c. Effect of Full-Cost Pricing on MILDEP Budgets

The top portion of Table 3-12 presents estimates of the total amount that each military department would have paid in subscriber charges if full-cost pricing had existed during FY78. The bottom half of Table 3-12 presents estimates of the actual amounts paid by the military departments for DCS services in FY78, including both subscriber charges *and* payments made "in kind." The in-kind payments are goods and services furnished by the military departments in connection with the provision of DCS services, including:

- depreciation for owned DCS equipment
- depreciation for satellites and launch costs

Table 3-12. DCS COST ALLOCATION: FULL-COST PRICING VS EXISTING METHODS

Estimated Payments by MILDEPS Under Full-Cost Pricing[a]						
	Army	Navy	Air Force	DCA	Other DoD	Total
AUTOVON	46,387	39,516	96,783	1,763	8,450	192,899[c]
AUTODIN	17,791	12,577	21,044	--	6,046[b]	57,458[d]
All Other DCS Service	176,835	149,848	320,417	59,234	31,824	735,158
TOTAL	241,013	201,941	438,244	60,997	46,320	988,515[e]
Actual Payment by MILDEPS FY78 ($000)						
DCS Charges	61,687	47,432	109,488	9,554	12,434	240,595
In Kind Charges						
Deprec. on Owned Equipment	59,202	41,665	129,538	189	--	230,594
Deprec. on Owned Satellites	--	--	166,347	--	--	166,347
O&M Cost	44,994	10,975	27,155	40,446	--	123,570
Military Personnel Cost	48,585	14,269	55,133	18,404	--	136,391
RDT&E	7,882	--	66,295	8,625	14,470	97,272
TOTAL	222,350	114,341	553,956	77,218	26,904	994,769[e]

[a]These estimates are based on the number of weighted units in being as of April, 1979 for AUTOVON and as of FY78 for AUTODIN, and on the estimated full-cost subscriber charges in Table 3-11.

[b]This includes DCA AUTODIN charges.

[c]This excludes $2,843 that non-DoD users of AUTOVON would be charged.

[d]This excludes $1,401 that non-DoD users of AUTODIN would be charged.

[e]Totals differ by the amount of DECCO profit and the amount of AUTOVON and AUTODIN charges that non-DoD users will be paying.

- O&M and military personnel costs for station operations, area operations, headquarters support, and engineering and installation costs
- RDT&E costs.

Comparison of the total amounts actually paid by the military departments with the amounts they would have paid under full-cost pricing indicates that the Air Force and DCA would have

paid less under full-cost pricing. The Army, Navy, and other DoD components would have paid more.

Table 3-13 shows the amounts paid by each military department for equipment (excluding satellites), O&M, and military personnel by geographic area. Satellite and overhead costs are not allocated by area. This Table gives a general impression of the geographic areas where each military department has its greatest investment. The Army tends to procure and maintain more equipment in the Pacific relative to the Navy and Air Force. The Air Force is the largest spender in Europe and CONUS.

Table 3-13. ESTIMATED DCS COSTS BY MILITARY DEPARTMENT AND AREA ($000) FY78

CONUS	ARMY	NAVY	AIR FORCE	DCA
Depreciation	10,042	10,823	55,249	189
O&M	22,034	3,299	2,305	
Military Personnel	16,606	5,585	11,077	
	48,682	19,707	68,631	189
EUROPE				
Depreciation	23,104	10,349	53,414	
O&M	21,448	1,480	1,969	
Military Personnel	24,433	6,167	20,632	
	68,985	17,996	76,015	
PACIFIC				
Depreciation	26,055	20,493	20,875	
O&M	19,425	4,207	1,377	
Military Personnel	17,001	8,936	11,075	
	62,481	33,636	33,327	

[1]Satellite, Overhead, and R&D costs were not allocated.

3. Decentralized Funding of DCS Procurement

The third category of potential causes of inefficiency in the DCS that we have examined is the decentralized funding of capital equipment. Most of the discussion in the earlier sections centered on the characteristics of *services*. Many of those services, however, are produced by DCA and the military departments, rather than simply leased from common carriers. In fact, commercial lease charges account for only 24 percent of the annual DCS cost estimate reported in Table 3-12. Further, $397 million or 40 percent of that cost estimate represents annual depreciation on owned equipment, and the FY78 expenditure on new equipment amounted to $191 million. Most of that amount was budgeted and paid for by the military departments.

As a result, many user-decisions on communications needs involve not only defining the service required, but also selecting the technology and equipment that will be utilized to supply it. It has been argued that permitting users to select technology as well as service leads to an increase in government costs. If this is true, it should not necessarily be construed as irrational or perverse behavior on the part of users. In many cases, they are merely responding to the information they receive about technology and equipment. For example, the price of a technology often does not correspond to its full cost to the government so that users have no incentive to choose the method which minimizes government costs. In addition, different technologies that provide what appears to be the same service may, in fact, have different quality characteristics. Thus, a user may choose a high-cost method in order to obtain its unique service advantages.

There is an additional problem, however, that the procurement funding process introduces. It often requires one military department to become a supplier of services to another.

DCA is the overall manager of the DCS, but does not itself provide transmission services. For commercial services, and for those provided by *existing* government-owned facilities, subscribers typically make requests to DCA which in turn allocates circuits and otherwise arranges for the provision of the service. But when a service request requires *new* government-owned facilities, the requestor submits a request through the DCS Five Year Plan (FYP) process. The facilities, however, will actually be procured by a military department, and the requestor may find himself negotiating with that department rather than with DCA. Because the military department which funds procurement has its own priorities, a requestor may not be able to obtain the service he wants. On the other hand, since the funds do not come from his own budget, cost may not be given the weight it otherwise would when he makes decisions about the services he requires. In either case, the equipment purchased may not be optimal from an overall point of view.

If procurement decisions and budgets were centralized in the DCA, the potential for non-optimal choices of equipment and circuits might be reduced. On the other hand, members of the government agencies which use DCA services argue that they need to participate actively in the procurement process in order to be assured that their requirements for communications services are satisfied. Under the present system, this latter argument cannot be ignored because buying services and purchasing equipment are almost synonymous wherever leasing is not prevalent.

As discussed at the beginning of this Chapter, efficiency is affected by both allocation and production. Allocative inefficiency would be manifested if decentralized procurement resulted in the wrong requirements being satisfied. Productive inefficiency would be manifested if the chosen requirements were produced at more than minimum cost to the government.

It is more difficult to characterize a result as inefficient when both allocative and productive aspects are involved than when only one is present. For example, two military departments may disagree on the importance of funding interdependent facilities. The first department wishes to delay funding because it has more important requirements to satisfy. But this delay increases the second department's costs of satisfying its own requirements. It is certainly conceivable that the first department's requirements are sufficiently important so as to justify the increase in costs suffered by the second department.

The following discussion concerns the present method of determining DCS procurement funding, and includes both a brief description and an evaluation of this process.

a. DCS Procurement Funding

The heart of the planning process for DCS procurement is the DCS Five Year Plan (FYP), which lists planned expenditures for each of five years, by project, appropriation category, and funding organization. The FYP is prepared by DCA, approved by the Office of the Secretary of Defense (OSD), and serves as guidance to the military departments in preparing their Program Objective Memoranda (POMs). Even though implementation of the FYP is far from automatic, the FYP does provide a major opportunity to devise a coordinated, systemwide plan for the satisfaction of future DCS requirements.

The FYP is DCA's plan for satisfying requirements submitted by unified and specified commands, military departments, DCA itself, and in some cases JCS and OSD. For procurement, the FYP includes requirements for facilities to provide DCS services not currently available, upgrades and replacements for existing facilities, and major new programs such as AUTODIN II and Secure Voice Improvement. Services which can be provided by existing facilities, or which are required within

two years, are requested through other channels. The FYP is developed with the participation of the interested DoD components, as well as DCA's engineering and program management staffs. Generally, DCA's objective in developing the FYP is to determine an efficient way of satisfying validated DCS requirements, including both engineering and temporal coordination of interdependent requirements. The FYP process also serves as a clearinghouse for DoD components to state requirements for services to be funded by other DoD components. For example, unified commands state requirements which must be funded by the military department with appropriate geographic responsibility. The give and take of the FYP process results in modifications in the requirements submitted as regards which will be satisfied, when, and in what technological manner.

The FYP is approved by OSD, and modified to serve as guidance to the military departments in submitting their POMs. Since the POMs are submitted on the assumption that funding will be only about 80 percent of what is assumed in the FYP, the military departments necessarily request less funding than is called for in the FYP. To reduce disputes between DCA and the military departments over how funding is reduced, DCA in the future will provide a detailed specification of its priorities for projects and sub-projects. Of course, the military departments may disagree with these priorities, and submit POMs based on their own objectives to some extent.

DCA identifies major disagreements with military department submissions during the programming and (later) budgeting processes. Such disagreements can be appealed to OSD for decision. In addition, DCA is invited to participate in OSD program and budget reviews. Such reviews focus on individual military department submissions. Other than the original FYP submission, DCA does not defend to OSD a comprehensive funding proposal for DCS procurement. After the President's budget

request is acted on by Congress, appropriated funds are apportioned to the individual DoD components. Since most DCS projects are too small to be line items in the budget, funds are not necessarily apportioned to the projects underlying the final budget request. Thus, DCA must participate in the apportionment hearings, and appeal changes which would have a serious impact on the DCS. Even after apportionment, DCA must monitor the obligation of funds by the military departments, since DCS procurement funds can be unilaterally reprogrammed to other purposes (up to $25 million if there is no Congressional interest) by the military.

b. Evaluation of Procurement Funding Process

The introduction of this section distinguished the user-oriented decisions regarding what and when new services should be provided, from the producer-oriented decisions regarding how services can be provided at *minimum cost to the government*. It is difficult to make this same distinction in practice, particularly when the consumers and suppliers are in many cases the same people.

DCS service requirements involving procurement are identified by unified and specified commands, defense agencies, the JCS, and the military departments. But responsibility for funding procurement lies with individual military departments and is based on geographic and technological criteria. Thus, military departments are frequently in the position of funding procurement to provide services for other organizations. As a result, the organizations requiring services often have no reason to consider government costs when defining requirements. On the other hand, since the funding military department can fail (at several stages) to provide procurement funds, the requiring agencies have no assurance that their needs will be met.

It is DCA's responsibility to assure that this system is effective. Since requiring agencies may have no incentives to control costs, DCA uses the FYP process to engineer least-cost solutions to requirements, and to coordinate the implementation of interdependent facilities. While this may reduce the cost of the requirements which are satisfied, it does not bring fiscal responsibility to the requirements-definition stage. Further, since military departments may fail to support procurement for DCS projects, or reprogram the funds, DCA must monitor the funding process and lobby for the required funds.

Whether this system functions well in practice is a difficult empirical question. Theoretically, it should work, providing DCA monitors and lobbies effectively throughout the process. Clearly, vesting responsibility to fund DCS procurement in the military departments gives them advantages in the final determination of what and when procurement is funded. This permits the military departments to consider their own priorities among individual DCS projects, non-DCS communications projects, and non-communications projects. Even if this flexibility results in frustration of DCS requirements or raises DCS costs, it could be judged beneficial overall.

In summary, the existing procurement system weakens fiscal responsibility in the definition of requirements, and has the potential to frustrate realization of the benefits of coordinated planning inherent in the FYP. But if DCA participates effectively in the procurement-funding process, at least the planning benefits could still be realized.

4. Summary

Although we have discussed the implications of our analysis within each of the three categories of causes of inefficiency, it may be useful as well to point out the linkages that exist among them, with particular reference to dedicated

circuits. There were two main themes that flowed through the first section on definition, adequacy and pricing of services. The first was that many users' needs are unique and may differ greatly from those of others. Services offered by common-user networks, however, have little variety and are often of low quality. Thus, subscriber demands are imperfectly met by the services offered. Second, the charges for common-user services are independent of usage and allocate average costs in a very aggregate fashion on the basis of access fees. In comparing common-user networks and their accompanying high access charges and non-differentiated services with dedicated circuits, many users find that dedicated circuits are more desirable.

The desirability of dedicated circuits is in many cases reinforced by the fact that prices paid for them by subscribers may include a smaller fraction of their true costs than do the prices paid for common-user networks. Dedicated circuits are a particular example of a more general phenomenon. Unless circuits and equipment are leased from a common carrier, their full cost is not likely to be reflected in the charges a user pays for their services. This problem is separate from that of not charging on the basis of usage, but the results are likely to be the same--misallocation of resources as subscribers make decisions about services based on the prices they pay rather than what it costs to produce the service.

Our discussion of the third category of causes, decentralized funding of procurement, suggests that the current process may lead to failure by some users to choose or obtain services efficiently, as well as to increased costs in producing the services that are chosen. But decentralized procurement funding does offer some amount of protection to the military departments which control appropriations, so that centralized procurement would create problems also.

In the following chapter, we make some suggestions and offer some recommendations about policies that might be followed in order to remove some of the causes of inefficiency discussed in this part of our report.

Chapter IV

PROPOSALS FOR IMPROVING EFFICIENCY IN THE PROVISION OF DCS SERVICES

In Chapter III we distinguished between two different aspects of inefficiency on the DCS, manifestations of inefficiency and causes of inefficiency, and stated that it is the causes that one can affect through changes in policy and that with the causes removed or reduced in importance, the manifestations will diminish and perhaps even disappear. In this chapter we build upon the analysis of Chapter III and discuss the potential beneficial effects of and the problems associated with policies directed at removing some of the causes of inefficiency. As in Chapter III, we have organized our discussion around the three main topics: definition, adequacy, and pricing of services; full-cost allocation and subscriber charges; and decentralization of procurement funding. Some specific areas we discuss within these topics are:

1. Definition, Adequacy, and Pricing of Services

   - Private-Line Services--Technology
   - Private-Line Services--Pricing
   - Private-Line Services--Implementation
   - Prices and Redefinition of DCS Services
   - Purchased Grades of Service--Administrative Precedence
   - Sizing of the AUTOVON Network
   - Redefining Service in Terms of Characteristics
   - User Choice Procedures
   - Miscellaneous Observations

2. Full-Cost Allocation and Subscriber Charges

- Methodology
- Comments on Calculating Prices

3. Decentralization of Procurement Funding

A. DEFINITION, ADEQUACY, AND PRICING OF SERVICES

As we have pointed out in a number of places, the main immediate objective for DCA in selecting a new policy regarding service choices offered to subscribers is to reduce dependence on dedicated circuits in those cases where common-user networks would be more efficient. We will discuss a number of different policies that might lead to that objective, beginning with a very simple one which would probably accomplish the majority of what DCA wishes to achieve with respect to dedicated circuits with minimum objection from subscribers. We shall first discuss the technical feasibility of the proposal and then explore the pricing and implementation aspects. Finally we shall turn to a more general examination of new ways of defining and pricing services and a general discussion of some DCA alternatives.

1. Private-Line Services--Technology

If subscribers are to be induced to switch from dedicated circuits to common-user networks, they must be assured they will receive the kind and quality of service that they desire and that they have with a dedicated line. Also, in many cases it may be that a dedicated circuit gives subscribers better service than they actually need but that the current common-user option is worse than they require. Thus, we should explore the technological feasibility of providing a range of private-line services on common-user networks with something equivalent to a dedicated circuit being the best. Since their

characteristics are quite different, we shall discuss separately AUTOVON and AUTODIN.

a. <u>AUTOVON</u>

Dedicated circuits provide a private-line service with specific circuits permanently reserved for the exclusive use of the subscriber. Thus, there is no possibility of calls being blocked by other subscribers. AUTOVON now provides a switched service with available circuits temporarily connected when subscribers dial their calls. Although a call attempt can be blocked when all appropriate circuits are in use, flash subscribers are able to pre-empt circuits being used for calls of lower precedence. AUTOVON also offers an off-hook feature whereby a particular destination is automatically dialed. When flash precedence is combined with the off-hook capability, the result is a switched service closely resembling a true private-line service. This off-hook flash service is minimally inferior to a dedicated circuit since there is a remote possibility that off-hook flash calls could be blocked if all appropriate circuits (including destination access lines) were in use for other flash calls. But the probability of such a blockage occurring is virtually zero during peacetime and very small even during an emergency. In addition, it is a probability that could be controlled through configuration of the network. Thus, off-hook flash service is nearly equivalent to the private-line service provided by a dedicated circuit and is currently available on AUTOVON.

Another potentially feasible alternative would be for AUTOVON to offer a true private-line service. A specific circuit would be assigned to the private-line subscriber, but would be connected through AUTOVON switches. Idle time on the circuit would be available for network calls, but the circuit could be pre-empted at the discretion of the subscriber. If

his pre-emption capability were absolute, this AUTOVON private-line service would have the same 100 percent non-blocking guarantee as a service on a dedicated circuit. In addition, if a specific circuit were assigned, it could be properly conditioned for data or secure-voice transmission. Technology to provide such a service is now being used in connection with the Alaska Telephone Switching System. If there were concern that flash calls randomly routed on the assigned circuit might be pre-empted, additional modifications would be necessary at AUTOVON switches so that the only network calls routed on a private-line circuit were of lower precedence than the private-line subscriber's precedence.

Thus far we have been discussing the feasibility of offering an AUTOVON service that is almost directly comparable to a dedicated circuit. If one were to consider the possibility of offering off-hook service or an assigned network circuit with precedence less than flash, however, the number of possible alternatives to dedicated circuits might be broadened. It is quite possible that some subscribers to dedicated circuits do not need the extremely high grade of service they receive but do require something better than ordinary routine. Private-line AUTOVON service with priority or immediate precedence might then be a satisfactory alternative, particularly if it cost less than private-line flash. In addition, such service would not require any modification of switches in order to ensure that no flash calls were pre-empted.

b. <u>AUTODIN</u>

Because AUTODIN is a store-and-forward, message-switching network, direct circuits are not connected between origin and destination subscribers. Thus, the concept of private-line service is not entirely applicable. The existing AUTODIN Query/Response service, however, provides point-to-point

message-switching service to up to six specific destinations. Coupled with flash precedence authorization and appropriate access line configuration, Query/Response could provide a rough equivalent of private-line service to subscribers whose requirements for end-to-end transmission line-speed were not high. For example, Query/Response with flash precedence would provide for message delivery to a particular destination with very little chance of delay, and would thus be a close substitute for a dedicated teletype circuit. A major limitation of Query/Response at present is that precedence above immediate cannot be used. This restriction precludes the use of this service for command-and-control purposes, and should be re-evaluated. In addition, Query/Response subscriber charges should be made more competitive, as discussed below.

Also, it should be noted that while AUTODIN II will greatly enhance the DCS common-user service offerings, its potential subscribers will still be concerned with the availability of the service when they need it. Hence the equivalent of private-line service should be considered for AUTODIN II as well.

2. Private-Line Services--Pricing

We now turn to the second important variable that subscribers consider when making decisions about service and the means to obtain it--price. In Chapter III we argued that the limited number of very broad definitions of service on both AUTOVON and AUTODIN, coupled with high, fixed access fees, provided large incentives for subscribers to purchase dedicated circuits when they had a restricted community of interest or required high grades of service. We also argued that the appropriate information subscribers should have in choosing between dedicated circuits and common-user networks was the actual cost of providing the service on each and we calculated some examples of such costs for AUTOVON.

Even if the pricing structure for DCS services continues to consist solely of charges for access, the charges for private-line services on the common-user networks should be based on the costs of providing those services. There is a difference, however, in the implications this policy has for AUTOVON as compared to AUTODIN. AUTOVON is being fully used (perhaps overused, depending upon what one considers to be the optimum grade of service), while AUTODIN has large excess capacity.

a. AUTOVON

The only circumstance under which it is advantageous to shift subscribers from dedicated circuits onto AUTOVON is when it costs less to provide the required service on AUTOVON than with a dedicated circuit. But if it does cost less, the subscriber should pay this lower rate. Only if the lower rate is passed on to the subscriber will he be likely to voluntarily adopt the private-line service offered on AUTOVON. In Chapter III we outlined a methodology for calculating the costs of providing service on AUTOVON. One explicit assumption we adopted was that it was necessary to increase the capacity on the network in order to provide service for a new subscriber without degrading the service of those already on the network. This is an assumption of full-capacity usage and it certainly applies to AUTOVON.

The primary determinants of the costs are the probability of use, the cost of AUTOVON switches and trunking, and the cost of additional access lines. Although it is possible to develop a general formula for calculating the cost of private-line service on AUTOVON as a function of the variables listed above, these costs will be unique for each application. Thus, the price for each private line on AUTOVON will also be unique and in not all cases will it be less than the cost of a dedicated circuit. Such a pricing policy would be a considerable break

with the tradition of non-selective pricing that has applied to AUTOVON in the past, but it is the only way in which to achieve a more efficient mix of private-line services using dedicated circuits and AUTOVON.

b. AUTODIN

The general methodology for the calculation of costs on AUTODIN is the same as that outlined for AUTOVON, with the primary components being the network switch and trunk costs, the probability of use, and the cost of any additional access lines. The difference between AUTOVON and AUTODIN is that AUTODIN has a large amount of excess switching capacity at present. This means that the network switches would not need to be increased in order to meet increased demands due to shifting subscribers from dedicated circuits to Query/Response services.[1] As a result, if costs were calculated on a strictly marginal basis assuming present capacity and present usage, the only elements that would enter in would be the cost of additional access lines and interswitch trunks.

Although such a pricing policy would almost surely generate large demands for Query/Response service, it would be wrong to follow it. One of the problems with AUTODIN is that, with all the excess capacity, the costs of the system (mainly switching costs) must be allocated among a relatively small number of users. If new Query/Response subscribers can be brought onto the system and contribute toward its total costs, the fees for regular users can be reduced and more full-service subscribers will be induced to use the system, thus reducing excess capacity and increasing the efficiency with which it is operated.

[1]If access capacity were reached at particular switches, subscribers would be connected to alternative switches, perhaps increasing circuit distances and costs.

There is considerable flexibility in choosing a proper price for AUTODIN Query/Response service. On the one hand, it should not exceed the cost that would be incurred if new switching capacity had to be acquired. On the other hand, it should not be below the full cost of additional access lines and inter-switch trunks. Where it should appropriately be set would depend upon the responsiveness of those needing service to a reduction in their costs as well as upon the effect that the new revenues raised would have upon prices for full-service subscribers. In any event, it should be noted that Query/Response will not be viewed as a close substitute for dedicated circuits so long as it is priced substantially higher. Some period of trial and error might well be required.

There is one caveat we must make about the pricing proposals put forth. Their use will contribute most to economic efficiency if *all costs* are included in calculating the costs of *all alternative means* of satisfying a desired service. For example, if dedicated circuits can be purchased by a subscriber at 15 percent of cost, while he must pay 80 percent of the cost of a common-user service, the common-user alternative must be *extremely* inexpensive before he will consider it and our pricing rules will have little effect in reducing dedicated networks. These problems are discussed more fully in Section B of this chapter.

3. Private-Line Services--Implementation

We have discussed rather extensively the problems associated with a proliferation of dedicated lines. We have also discussed a number of reasons why subscribers find the common-user networks unsatisfactory, the principal ones being high cost and poor grade of service. It seems apparent that, even though the overall cost to the government might be less if they were to do so, subscribers with dedicated circuits prefer

not to be restricted to the common-user system. Nor is this behavior irrational, given the current price structure and quality of service. Attempting to force dedicated subscribers to use common-user networks could create political problems. We have recommended that DCA offer alternative services which utilize the common-user networks but are equivalent to or better than dedicated circuits in terms of price and grade of service. The recommendations that follow presuppose that such services can and will be offered.

a. Recommendation #1

We recommend that DCA develop a set of criteria, acceptable to the defense agencies, which will permit a comparison to be made between the costs of satisfying a particular point-to-point requirement for private-line service by using: (1) a dedicated circuit and (2) private-line capability on a common-user system. These costs should be determined on a marginal-cost basis, i.e., considering the cost of adding one more circuit (or network) to an existing system. Examples of the kinds of costs that should be included in the calculation are contained in Chapter III.

b. Recommendation #2

Using the criteria developed, DCA should evaluate each new application and offer subscribers information on which is the cheaper way of providing private-line service. The cost comparison should be based on full economic costs, including depreciation and O&M on government-owned equipment where applicable. These costs should be reflected in the subscriber charges the user would pay, so that his incentives are consistent with making the choice which is efficient from the viewpoint of the government.

c. **Recommendation #3**

DCA should compile and maintain an up-to-date inventory of dedicated circuits and networks. The inventory should include data on both the dedicated circuits and their common-user alternatives, including:

- Length of dedicated circuit
- Technology (e.g., satellite, multiplex)
- Lease costs (if any)
- Capital costs (if any)
- O&M costs (if any)
- Distance from each end point to nearest AUTOVON or AUTODIN switch
- Shortest trunk distance between appropriate AUTOVON or AUTODIN switches
- Estimated level of usage during busy hours (i.e., percentage of capacity occupied).

One of the principal problems we have encountered, which has made it impossible to do a definitive study of the excess cost of providng dedicated circuits, is the lack of detailed information on such circuits. Only with information on individual circuits can appropriate cost and value comparisons be made between dedicated circuits and common-user systems. Such information should be collected in such a way to minimize the need for classification.

d. **Recommendation #4**

DCA should rank the inventory of circuits and networks according to the excess cost of dedicated lines compared to the specific alternative common-user systems. It should then undertake to shift users (with their consent) from dedicated circuits to the private-line common-user capability, in those cases where government costs can thereby be reduced.

e. Recommendation #5

As switches and transmission equipment are improved and replaced, as switch locations are changed, and as technology improves, the inventory data for each circuit should be updated, new cost comparisons made, and new rankings of candidates for moving to the common-user systems identified.

4. Prices and the Redefinition of DCS Services

In Chapter III we examined how subscriber charges that are insensitive to usage could lead to certain inefficient service decisions by DCS customers. If charges are made more sensitive to the use which individual subscribers make of the common-user networks, those subscribers will be better able to weigh the values of different service choices against their costs (to the government). This will produce greater efficiency in the management of usage, the configuration of network access, and the choice among alternative networks and systems. Two major methods for designing more sensitive subscriber charges are described here:

- usage-sensitive pricing;
- restricted-service pricing.

a. Usage-Sensitive Pricing

The most flexible method of pricing the services of common-user networks would be the design of subscriber charges which were sensitive to actual usage and, in particular, to the real costs of providing the services used. Such usage-sensitive charges have been recommended for AUTODIN and AUTOVON in previous IDA studies.[1]

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[1]See Beazer, W., et. al., *Cost Allocation for AUTODIN: An Economic Analysis*, Institute for Defense Analyses, IDA S-487, September 1978 and Beazer, W., *Pricing and Cost Allocation for AUTOVON*, Institute for Defense Analyses IDA S-506, forthcoming.

Access charges would continue to be relevant since certain government costs depend on the number of subscribers who have access to the networks. But subscriber charges would also have a component which depended on the usage made of the networks by the subscribers. The usage component would depend upon parameters which customers control and which affect costs, including:

- Number of calls or messages,
- Length of calls or messages,
- Distance calls or messages are transmitted
- Characteristics of particular origins and destinations
- Times of day and week at which communications occur,
- Precedence levels of calls or messages.

(1) Benefits of Usage-Sensitive Pricing

Usage-sensitive subscriber charges would provide military departments with additional incentives to restrict low-valued usage of the common-user networks. Such restrictions would increase network availability for more important calls or messages (either by improving the grade of service or by replacing low-valued with higher-valued calls or messages). In addition, usage charges which increased with the precedence level claimed for each call or message would provide incentives to maintain precedence discipline. At present, price incentives do not discourage the use of command-and-control precedence discipline.

Usage-sensitive prices would also encourage military departments to base certain tradeoff decisions on the government cost involved. For example, a lightly-used access line would cost (the subscriber and the government) less than one

which was heavily-used. This would give the military departments more freedom to provide access lines for subscribers for whom a good access line grade of service was more important than maximum utilization. It would also reduce incentives to over-centralize access line configuration. Further, usage charges would provide military departments with incentives to manage the types of usage which occured. For example, usage charges would reflect the higher (government) cost of long-distance busy-hour communications. The military departments could then save money (for themselves and the government) through appropriate substitutions and restrictions on long-distance, busy-hour calls and messages.

Usage-sensitive charges would have a major impact on the relative costs to subscribers of DCS common-user networks, dedicated circuits, and commercial switched networks. For low-usage subscribers, access charges would no longer pose such a formidable barrier to joining the DCS common-user networks. At the same time, high-usage subscribers would no longer be subsidized by other subscribers, and might find it less costly (for them and the government) to order dedicated circuits. (That is, with high point-to-point utilization, the circuit-sharing advantages of networks are small, and could be outweighed by the costs of circuitous routing of access lines and backbone trunks.) In general, dedicated circuits and commercial networks would lose the advantages they presently derive from the rigid structure of DCS common-user subscriber charges.

(2) Implementation of Usage-Sensitive Pricing

Bills for usage-sensitive subscriber charges would be sent to the communications commands of the military departments (and to other user agencies). These bill should be supported by detailed information regarding each long-distance call or message, including origin and destination extension numbers

and locations; time-of-day, date, and length of call; precedence claimed; and subscriber usage charge.

The communications commands could use this information in planning to meet communications requirements, when budget restrictions prevented their satisfying all of the service requests they received. In addition they could provide the information and appropriate incentives to the operational commands, to motivate them to control the usage of particular services.

Control over the usage of particular individuals could be accomplished by either administrative or technical means. Under administrative controls, criteria would be designed to govern the number, destination, length, time-of-day, and precedence of calls and messages sent by particular users. These criteria would vary depending on operational missions and the particular users involved. Operational organizations would enforce compliance with their criteria with the aid of detailed call or message information (forwarded by their communications commands), at least on an exception or random basis.

Direct usage controls could also be implemented at the local communications center. Particular extensions would be authorized to make only certain types of calls or messages. These restrictions would apply to distance, time-of-day, length, or precedence. Such technical restrictions are particularly easy when new equipment is installed, such as the electronic PBXs.

A major prerequisite to implementing usage-sensitive pricing is the availability of equipment and software for collecting detailed call and message information for billing purposes. As shown in IDA Study S-504,[1] detailed message information can

[1]Fry, J. "*Implementing Usage-Sensitive Charges for AUTODIN*," Institute for Defense Analyses, S-504, forthcoming.

be obtained from data already collected at the AUTODIN switching centers, providing appropriate software modifications are made. Special care should be taken to see that similar information can be recovered at the AUTODIN II switches. Since it is more expensive to add the required Automatic Message Accounting (AMA) equipment to existing AUTOVON switches, it is particularly important that this capability be built-in on all replacement switches.

c. Restricted-Service Pricing

A second method of increasing the sensitivity to usage of DCS subscriber charges would be to offer common-user services which were much more restrictive than those presently offered. Through technical controls at the backbone switches, particular subscribers would be allowed to communicate only with narrowly defined communities of interest. These communities could be defined in terms of particular numbers, specific geographic areas, or different distance bands with which subscribers would be allowed to communicate. Such services should be much more restrictive than the maximum calling areas now available (and which would continue to be offered) on AUTOVON, AUTODIN, and the other switched networks.

Similarly, services could be defined restricting hours of use for particular subscribers. In addition to the present full-time services, other services would be limited to particular time periods (e.g., morning, afternoon, non-busy hours).

Restricted services could be offered in conjunction with the usage-sensitive pricing scheme described above (which proposed charges for individual calls and messages), or with the present method of charging only for access. Since service restrictions would closely circumscribe the hours and destinations subscribers could call, charges assessed for access only would still be somewhat sensitive to the type and amount

of usage. Such charges should be based on the cost to the government of average amounts and types of services within the restricted categories.

Such charges would provide some of the same efficiency incentives discussed above for usage-sensitive pricing. Since charges for full-time service would be higher than for part-time and non-busy-hour service, subscribers with part-time requirements would no longer have to subsidize full-time users. This would permit the choice between common-user networks and dedicated circuits to be based more closely on the (government) costs of serving the relevant subscribers. Charging based on service-available hours would also provide incentives to the military departments to control the amount of usage and shift part of it to non-busy hours.

Similarly, community-of-interest restrictions would reduce apparent cross-subsidization from those who call short distances to those who call longer distances. Further, services for particular subscribers would be configured based on the destinations essential to mission performance. So, low-value communications would be reduced because there would be less capacity available to non-essential destinations (and at non-essential times). Subscriber access lines could be used for different communities of interest at different hours, depending on subscriber needs and the costs of alternative restricted services.

Again, the efficiency incentives of offering restricted services would impact directly at the level of the communications commands of the military departments. Because the restrictions would occur at backbone switches, the communications commands could use them to gain the attention of operational organizations with regard to controlling usage. At the level of the local communications center, usage would still be controlled by administrative or technical means. Detailed call and message information would still be helpful.

Charging by the call or message would permit subscriber charges to reflect closely the government costs of the usage which each subscriber imposes on a network. Restricted-service pricing would not be as sensitive as that, but would track government costs more closely than the existing methods. Thus, the restricted-service option should be considered as a less-preferred substitute in the event that charging by the call or message cannot be implemented.

5. Purchased Grades of Service-Administrative Precedence

For subscribers without command-and-control justifications for flash precedence, the grades of service available on AUTOVON are often inadequate. In many cases, these lower precedence subscribers are forced to endure the costs imposed by AUTOVON congestion, but in other cases they obtain commercial service or dedicated circuits. But AUTOVON could offer services which improved grades of service for subscribers willing to pay the government's incremental costs for providing those services. If the money were indeed spent to expand AUTOVON when necessary to provide the new services, then there need be no degradation of service to other subscribers.

Perhaps the simplest way to improve grades of service for particular subscribers would be to offer new precedence levels for purposes other than command and control. These new precedence levels would be offered to subscribers willing to pay their incremental costs, and able to meet new JCS criteria governing the validity of their needs. Grades of service to these subscribers would improve because of their capability to pre-empt calls of lower precedence when necessary. Of course, grade of service would deteriorate even more for routine callers, since their calls would be more likely to be interrupted than at present. AUTOVON could be sized so as to provide specific target levels of grade of service to each

precedence level, at least during non-emergency periods. The new precedence subscribers could not pre-empt command-and-control flash calls. In some cases, it might be desirable to offer pre-emption rights which would expire when an emergency was declared. By pricing these new precedence levels at incremental cost to the government, they would be attractive to users of dedicated circuits and commercial long-distance, at least in those cases where AUTOVON had important cost advantages in providing those services. In addition, new precedence levels would permit preferential treatment for the more important of the present routine calls, thus reducing waste associated with random allocation of circuits to routine call attempts.

Other methods of improving grades of service for particular subscribers could be designed by DCA engineers, based on their knowledge of existing and future technology. For example, pre-emption could automatically be assigned to subscribers after specified proportions of their call attempts were blocked. Or sub-networks could be designed for specific communities of interest, and sized so as to provide a target grade of service. The sub-network would be interconnected with AUTOVON, so that sub-network circuits could be used for general AUTOVON calls when they would otherwise be idle. But the sub-network would retain the right of pre-emption when it needed the circuits.

6. Sizing of the AUTOVON Network Service

An obvious way to improve AUTOVON service would be to greatly increase AUTOVON's calling capacity. While this would be inefficient by itself, some expansion of AUTOVON funding might be beneficial if done in conjunction with other proposals discussed in this chapter. The discussion in this section will consider:

- determining AUTOVON sizing,
- the impact of other proposals on available funds.

a. Optimal Network Size

AUTOVON exists to satisfy command-and-control transmission needs. Thus, its minimum size is determined by the requirement for non-blocking service for flash calls during emergency periods. A separate network has been necessary in CONUS because flash non-blocking service (through pre-emption capabilities) was not available on the commercial networks (although this may change in the future). Overseas, AUTOVON is necessary because adequate commercial service is frequently not available at all.

There are a number of reasons why it might be efficient to use AUTOVON rather than commercial long-distance for administrative calls. First, because much of the command-and-control capacity is not needed for that purpose during non-emergency periods, it is efficient to utilize it to provide for calls with other purposes, including administrative calls. Further, once a network is in place, the incremental costs of expanding it to handle additional calls may be less than the costs of handling those calls by alternative means. In CONUS, for example, AUTOVON has been expanded so that up to two-thirds of AUTOVON trunks are unnecessary for command-and-control purposes. Third, the rates of commercial carriers discriminate against buying service by the call, and in favor of buying it by the circuit (which is how AUTOVON leases its trunks). And finally, AUTOVON saves money by providing a much worse grade of service than could be purchased commercially.

The appropriate size for AUTOVON (over and above command-and-control requirements) is partially a question of how much money can be allocated for non-command-and-control transmission, and partially dependent on the relative costs of various methods. While the allocation question is a matter of priorities set by OSD and the military departments, this study makes two observations. First, the costs that AUTOVON congestion imposes on its users (as discussed in Chapter III above) should be considered

in determining priorities. And second, the priorities themselves are defeated to the extent that restricting AUTOVON funding causes users to seek (and to obtain) commercial services or dedicated circuits, for low-priority purposes.

Whether AUTOVON is indeed the low-cost method of providing service can be decided to some extent on a case-by-case basis. That is, if DCS subscriber charges reflect government costs, then individual subscribers can determine whether AUTOVON is the least-cost solution in their particular situation. The correct size for AUTOVON, then, would be determined by the number of subscribers (together with the amount of their usage) willing to pay government costs for AUTOVON services. But for this sizing method to work, it is important that AUTOVON offer services comparable to those available by other methods. If not, users may choose other systems to obtain services which AUTOVON could have provided at lower cost. In particular, correctly pricing a P13 grade of service for routine AUTOVON users would provide no information on how many subscribers were willing to pay government costs for a P03 grade of service.

b. Impact of Other Proposals on AUTOVON Funding

If AUTOVON is made more attractive to potential users through the design of efficient subscriber charges and new services, then there will be less competition for funds from requirements for dedicated circuits and commercial alternatives. This might induce OSD to approve increased funding for the AUTOVON backbone, in addition to inducing military departments to increase funding for AUTOVON access.

Further, if usage-sensitive subscriber charges are adopted, the resulting incentives will reduce the proportion of AUTOVON usage which is wasteful or of very low value. This could increase OSD's willingness to approve additional backbone funding, since such funds would be spent to provide valuable

services. In contrast, the present lack of control over usage would cause additional funding to support a mix of wasteful and valuable calls.

7. Redefining Services in Terms of Characteristics

Existing service arrangements and subscriber charge designs presently lead subscribers to make inefficient service choices. Previous sections of Chapter IV have proposed new pricing methods and service offerings to motivate DCS subscribers to make efficient choices. An alternative approach would be to redefine the terms on which subscribers requested services. Under this approach, services would be redefined in terms of required service characteristics and subscribers would not be permitted to choose the DCS systems or methods by which services were provided. DCA would then choose a method to provide the required service at least cost to the government.

The following discussion argues that this alternative approach is unnecessary and may be inefficient as regards services supplied by DCA or commercial carriers. But some redefinition of the terms of service should be considered in the case of services provided by military departments to other users.

Subscribers presently choose services by selecting a DCS system. Frequently, subscribers choose methods which do not minimize government costs. This occurs in part because distorted subscriber charges mislead subscribers as to which methods are really least-cost for the government. It also occurs because alternative methods are not always perfect substitutes for each other, so that subscribers choose more costly methods in order to obtain certain service characteristics.

If services were designed solely in terms of the characteristics users required, then DCA would be free to select the least-cost method of providing those services. But it would still be necesary to base subscriber charges on the

government costs of providing particular services. This remains necessary because subscribers would still need that information in order to make efficient choices among services.

Also under this alternative approach, services could be defined so as to eliminate certain quality choices which subscribers are presently able to make. While such eliminations could reduce government costs, they might create serious problems since only the subscriber has the information necessary to judge the contribution a particular service characteristic makes to his mission. Certainly, DCA should not put itself in the position of making such judgments.

The present study generally favors giving subscribers as many choices as possible. Then when subscribers make choices which seem to raise government costs inefficiently, such choices give DCA valuable information. That is, they warn DCA that services available on common-user systems need modification, or that subscriber charges do not reflect government costs. Thus, if the service and pricing proposals discussed above are implemented, problems associated with customers choosing systems and methods should be reduced to manageable proportions.

But a problem may exist with respect to the terms under which users obtain services from other military departments. As discussed in Chapter III, even though DCA acts as a clearinghouse for such interdepartmental requests, what services are actually provided depend on the priorities and service needs of the military departments providing the services. Thus, requestors from other military departments may not find the DCS responsive to their needs. In addition, the current system does not hold such requestors accountable for the costs other military departments incur when providing the requested services.

For these reasons, serious consideration should be given to a tighter centralization of management of the provision of DCS services on government-owned facilities. The organization should be restructured so that users can request services from DCA, rather than negotiating with other military departments. Subscribers should pay for the government costs of the services they request. This restructuring of services provided by government-owned facilities may require centralization of the authority to fund procurement.[1]

The major impact of tighter centralization would be to make DCS service more responsive to the needs of subscribers using facilities provided by other military departments, and to impose fiscal responsibility on those subscribers. It should be noted, however, that this approach would make DCS service less responsive to those subscribers whose needs are now satisfied on facilities provided by their own military department.

8. User Choice Procedures

It is important that fiscal responsibility influence communications decisions within the military departments as much as possible. Budget and price incentives should affect the determination of communications needs, and of how they are to be satisfied. This study makes two observations:

- Budget pressure should be felt during the requirements validation process;
- Budget pressure should be felt below the communications command level.

a. Budget Pressure and Requirements Validation

Needs for services are approved during the requirements validation process. And to a large extent, the means of

[1]See Section C, this chapter, for a more complete discussion.

satisfying those needs are also determined in that process. By the time requirements have been approved throughout a high-reaching chain of command, it is frequently too late for budgetary pressures to influence the definition of need or the choice of means. The major impact of budgetary pressures is then to force choices as to which validated requirements will be funded. While the communications commands participate at various stages of the validation process, their efforts would be more effective if users themselves felt fiscal responsibility for their communications choices.

b. Extending Budget Pressures

The design of communications budgeting procedures for the military departments is a complicated task, and certainly beyond the scope of this study. But extending fiscal responsibility in the direction of communications users should be encouraged. In some cases, it might be best to allocate communications budgets to major commands or smaller organizational units, and to allow them to determine what services to fund. But more limited steps would also be beneficial. The Air Force, for example, is allowing major commands to determine how to spend a portion of the non-common-user communications budget. Similar delegations of responsibility could be made with regard to budgets for common-user systems. For example, under usage-sensitive pricing, AUTOVON spending limits could be designated for particular major commands or military installations. The users would then decide what tradeoffs to make between access lines and usage within the prescribed limits.

9. Miscellaneous Observations

a. Managed Allocation of AUTOVON Circuits

Low-precedence subscribers usually obtain AUTOVON circuits by re-dialing call attempts until, by chance, an appropriate

circuit happens to be available. Time is wasted in re-dialing, and planning is frustrated by uncertainty as to how long it will take to obtain a circuit. In addition, all call attempts (of the same precedence level) receive the same treatment, even though some of these calls are more important than others.

In some cases, these problems are avoided at the PBX level by having an operator manage the allocation of AUTOVON access lines. The operator receives call requests, determines the importance of the calls (based on pre-established criteria), and notifies the requestor how long his wait will be, based on how many requests are queued ahead of his. These same functions can be performed automatically by the new electronic PBXs being installed in many locations. Similar functions could be performed in the future at AUTOVON switches and by destination PBXs. For example, the destination PBX could automatically call the originator when a desired destination extension became free. These methods of managing the allocation of AUTOVON access lines and trunks would improve service for individual users. In addition, they would reduce the number of trunks and access lines tied up by blocked call-attempts, thereby increasing capacity for completed calls. Hence, further consideration of such methods should be encouraged, as the required equipment becomes available.

b. Data-Conditioned AUTOVON Trunks

The conditioning of AUTOVON voice trunks makes them inadequate for transmission at line-speeds exceeding 2,400 bits per second (bps) in most cases. This limitation causes some data and secure-voice subscribers to turn to dedicated circuits, and forces others to endure unsatisfactory service on AUTOVON. Specially conditioned voice circuits could be used to transmit at up to 9,600 bps. Past attempts to offer data-conditioned AUTOVON trunks failed due to difficulties of keeping them available for data subscribers and at the same time using them

for voice calls when they would otherwise be idle. The possibility of again providing data-conditioned trunks to subscribers willing to pay the incremental costs should be kept in mind, particularly as new switching technology becomes available, making it easier to handle the dual-network problems.

c. Delivery Time on AUTODIN

Because AUTODIN is a store-and-forward network designed primarily for message traffic, it is difficult to devise new services to attract subscribers with high-speed data requirements. Guaranteed Sequential Delivery and Query/Response are commendable innovations, but can only go so far in attracting high-speed computer applications.

One new service which could be considered is the introduction of new precedence levels (similar to those discussed in 4A5 above). This could attract subscribers who now use dedicated circuits because their command-and-control precedence level does not permit a sufficiently short time for message delivery on AUTODIN. The primary benefit for subscribers to these new precedence levels, however, would be in obtaining preferential treatment at local communications centers and access lines, rather than on the AUTODIN backbone itself.

d. Availability and Line-Speed for AUTODIN II

Naturally, there will be excess demand for the capacity of AUTODIN II from time to time. When that occurs, capacity will be rationed by forcing some users to wait before using the network, and by reducing the effective line-speed at which data are transmitted for other users. Clearly, how and when capacity is rationed will have an important bearing on whether AUTODIN II can provide service which is truly equivalent to that available on dedicated circuits. Rationing procedures should be designed

so that subscribers can have some choice in the quality of service they receive. Thus, different services could be defined in terms of average waiting times and expected transmission line-speeds during busy hours. These services would not conflict with command-and-control requirements, and would be priced based on the incremental costs to the government of providing them. Subscribers could then choose among qualities of service based on what they were worth to them, and on what it cost the government to provide them. Those who truly needed service equivalent to a dedicated circuit would obtain it on AUTODIN II when that cost the government less than a dedicated circuit.

B. FULL-COST PRICING

In Chapter III, DCS costs were estimated to illustrate the magnitude of the costs that were not included in any subscriber charges and the uneven way in which costs were distributed among different services. When subscriber charges are not closely related to costs, users have incentives to make inefficient service choices. The subscriber charges mislead them as to the relative government costs of services provided by the various DCS systems, and by commercial suppliers.

The first part of this section discusses issues related to the design of subscriber charges which would fully allocate the economic costs of providing the particlar services. The discussion covers the following topics:

- What costs should be included?
- Which DCS systems should have subscriber charges?
- How can accounting procedures be modified to permit full-cost pricing?

The second part discusses some general propositions about pricing that are valid whether full costs are included or not.

1. Methodology

a. What Costs Should Be Included?

Economic costs include all costs which must be incurred in order to provide a service, including the cost of:

- Equipment, buildings and other capital investment;
- Operating and maintaining these facilities;
- Necessary research and development;
- Overhead for managing the relevant system.

Subscriber charges should reflect all of these economic costs. Which costs are included should not be determined arbitrarily, as is the case at present. For example, equipment costs exist, whether the equipment is provided by a common carrier under a lease contract or by government ownership. Yet present rules exclude depreciation on government-owned equipment from subscriber charges. Similarly, operating and maintaining facilities requires resources, whether the work is performed by contractors, civilians, or military personnel. Yet present rules exclude military personnel expenses from subscriber charges. In the same way, research and development and management overhead (except DECCO) are excluded from subscriber charges, when these services are provided by DCA or the military departments. But commercial lease charges include the R&D and overhead costs relevant to providing the leased service.

These arbitrary rules on what costs can be included result in great variation in the proportion of the economic costs that subscribers must pay for the different DCS and non-DCS systems. Thus, subscriber charges cannot accurately inform subscribers as to the government costs of the systems among which they choose. Accordingly, the method of determining subscriber charges should be modified so that economic costs can be included on the same basis for each system.

b. Which DCS Systems Should Have Subscriber Charges?

As a general rule, subscribers to all DCS systems should pay for the economic costs incurred by the government in providing their service. Inevitably, failure to use subscriber charges for particular systems leads to distorted incentives affecting which services and systems subscribers choose, and how they use them. This is a particularly acute problem now for dedicated circuits provided by government-owned facilities. Because subscribers do not pay for such circuits (when available), they have reduced incentives to consider the government cost savings which are frequently available on common-user systems. Subscriber charges should be instituted for such circuits.

Subscriber charges should also be considered for other systems which do not now have them. Subscribers connected to AUTOSEVOCOM switches, for example, do not pay anything for their use of the AUTOSEVOCOM and AUTOVON backbones. Nor are ARPANET and WIN users charged for access to those networks (except at the discretion of the sponsor of the switch to which they are connected). But when these networks are folded into AUTODIN II, the subscriber charges of that system will apply.

c. How Can Accounting Procedures Be Modified to Permit Full-Cost Pricing?

Under present methods, subscriber charges are determined so as to allocate the recurring costs financed by the Communications Services Industrial Fund (CSIF). The adoption of full-cost pricing would thus require changes involving what was financed by the CSIF. What procedures are eventually adopted is a complicated management question, and the following comments only touch on certain economic considerations.

Historical accounting costs provide a starting point for measuring economic costs. Such costs do not reflect

replacement costs due to changes in technology and in prices. But the charges of regulated common carriers are also based largely on historical accounting costs. Thus, using such costs for DCS subscriber charges would not greatly distort the important comparisons with commercial prices.

Using historical accounting costs to approximate the economic costs mentioned above would require detailed records at DCA of all DCS-related expenditures. Subscriber charges based on such costs would cause the CSIF to collect substantially more revenue than it currently spends. Thus, either the excess revenue would have to be transferred out of the CSIF (say, by OSD) or the CSIF would have to finance additional DCS costs. If the CSIF financed additional costs, this could take the form of reimbursing military departments for their DCS expenditures, or of directly financing additional items, such as capital procurement. (In the discussion of procurement practices below, the efficiency implications of centralizing DCS procurement funding are discussed.)

Because DCS subscriber charges will be compared with commercial lease and toll charges (when users choose services), the levels at which DCS charges are set is important. Thus, to the extent possible, CSIF funding methods should be arranged to permit efficient pricing.

2. Comments on Calculating Prices

The discussion above and in the early parts of this chapter has proposed new general approaches to the design of DCS subscriber charges and the inclusion of full costs. Following are some preliminary observations regarding how efficient prices might actually be calculated. We proceed by first discussing how prices might be calculated for a basic communications service, and then how services with different special features might be priced. Our purpose here is not to actually lay out

suggested prices for any proposed DCS service, but to describe methods that one can use to determine prices.

For all types of service, we will be trying to answer the question: If two services are identical in all respects except for one characteristic, how would the difference in this one characteristic affect the cost of providing the service. This difference in the cost of providng the service should be reflected in the price of the service to users.

The following characteristics of communications services were discussed in Chapter II: transmission capability, delivery time, availability of service, community of interest, and timing and amount of use. Discussing the following topics should give rules concerning the pricing of most of these service characteristics:

- Price per call-second
- Distance
- Transmission capability
- Availability of service--precedence levels
- Other characteristics
- Cream-skimming
- Interim pricing problems.

a. Price Per Call-Second

In order to determine the price to be charged for a communications service, the incremental cost of a unit of service must be calculated. Suppose for the time being that a unit of communications service is a call-second. In order for any user to be able to consume this output he must have access to the network (where "network" may consist of just one circuit). Thus, the cost of providing backbone service to a user can be divided into two categories: access and use. Access costs are those which vary with the number of connections, and are related primarily to the backbone switches. Usage costs are

those which vary with the number of calls or messages, and are closely related to both switching and network trunking. To reflect this cost breakdown, subscriber charges should include both an access fee and a usage charge.

The price per unit of a service should be based on the marginal cost to the government of providing that unit. The most practical way to price a call-second would be to divide expected usage into the economic costs associated with usage of the particular service or network. This average-cost method was discussed in the earlier IDA paper.[1] That report used average cost per unit as a starting point for discussing pricing by geographic areas and precedence levels. This is the starting point for pricing DCS services in this report as well. In the following sections, we describe how this costing method can be modified to calculate cost and appropriate prices for some of the characteristics that the DCS might offer.

The average cost calculated as described above is the actual average cost of providing the service with the existing quality of service. Prices set at these levels would cover total costs with the existing number of users and traffic. For the time being, our discussion will consider how prices, which simply cover total current costs with existing capital and quality of service, should be set. What happens if the grade of service is not the desired grade of service is discussed later.

b. Distance

An easy way to price calls of different distances is to define a unit of communications service as a call-second-mile. Each call-second of traffic could be weighted by the number of miles it was transmitted and this total divided into the total

[1]Beazer, et. al, "*Pricing and Cost Allocation for AUTOVON*", Institute for Defense Analyses, IDA S-506, forthcoming.

cost of the network to generate an average cost per call-second-mile. Notice, however, that this method implies that the cost of a two-minute call to someone 100 miles away is equal to the cost of a one-minute call to someone 200 miles away. If these costs are not equal (and it is likely that they are not), prices set equal to the average cost per call-second-mile may lead to inefficient decisions by customers.

A better approach to pricing for different distances would be to learn how cost varies with distance. That information could then be used to determine how the unit charge should vary with distance. It might be appropriate to use the same rate per call-second-mile for all distances, or to change that rate for different distance intervals. Or it may be most efficient to price by the call-second within certain distance ranges: for example, the price per call-second for calls between 0 and 100 miles would be the same. Price per call-second might then jump to a higher level for calls between 100 and 300 miles. Discussion of pricing by bands of this type can be found in the earlier IDA AUTOVON report.[1] Which method is efficient depends on how costs actually vary. An important consideration in pricing dedicated circuits is that the costs of circuits differ depending on the transmission media used. To the extent that a customer's requirement dictates what media must be employed, subscriber charges should vary with the media involved. For example, pricing circuits according to the transmission media used would result in virtually a fixed price for a satellite circuit, regardless of distance. This would have the advantage of discouraging users with short distance requirements from purchasing satellite circuits. The satellite capacity would then be used only by users with long-distance requirements. However, pricing individual circuits according to the specific transmission media used could cause some short-run utilization

[1]Beazer, et. al., *Ibid.*

problems (queues for less expensive transmission media and unused capacity in more expensive but in-place equipment until DCS capacity could be adjusted).

c. Price of Tranmission Capability

Now consider services identical in all respects except that transmission capability differs, where transmission capability is measured in bits per second. Their prices should differ according to the cost of providing the capability.

The transmission capability of a circuit depends on the kind of modems, conditioning equipment, and other kinds of line termination equipment. Price could be calculated for different categories of transmission capabilities such as:

- Teletype
- Voice-grade
- 4800 bits per second
- 9600 bits per second
- 56,000 bits per second.

In order to estimate the cost of supplying circuits of a particular grade, one could estimate the total cost of providing a trunk which has the equipment necessary for that transmission capability. This total cost could then be divided by the maximum number of channels derivable from the trunk to generate a cost per channel.

d. Availability of Service

One measure of the availability of service is the grade of service, or the probability that a user will be unable to make a call. As discussed above, the grade of service at present depends on a subscriber's precedence level.

Conceptually, there are two equivalent ways of deriving prices for different precedence levels.[1] The first method is to determine the constant-quality marginal cost of a service and set prices equal to it. This constant-quality marginal cost is the increase in total cost that must be incurred in order to increase output by one unit without affecting quality of service on the network. This price would be equal to the cost of adding a user to a network or sub-network, including the cost of additional capital needed to maintain the original level of quality.

The second method of determing prices for different precedence levels is to set prices equal to the direct costs of adding a user to the network excluding capital costs but including a congestion toll. The congestion toll would equal the amount that all other users must be paid for the loss in quality due to increased traffic. Alternatively, this toll would be the amount that users would be willing to pay to decrease traffic and thus increase quality of service. The congestion toll equals the value of a unit of output times the amount of output affected times the change in quality due to the additional traffic. This method may be useful in generating rules concerning relative prices between different precedence levels. Both methods generate the same level of prices and both methods imply that higher precedence levels should have higher prices.

Using the constant-quality marginal-cost method, the price of a unit of service with flash precedence (with P00 grade of service) would equal the cost of a unit of flash traffic, where the cost includes the capacity necessary to maintain grade of service to all other users of the network. The price of a unit

[1]This discussion is based on a model developed in "Reliability and Peak-Load Pricing," by T. R. Saving and Arthur De Vany, unpublished manuscript, 1979.

of service with immediate precedence (with a grade of service greater than P00) would equal the cost of providing service for one unit of immediate service without changing quality of service to all other users. Since the flash user must have his calls blocked less often (in fact, this user must never be blocked) than an immediate user, the additional capacity needed to provide service for a flash user is greater than that required for an immediate one.

Using the congestion toll method of pricing, higher precedence levels would have higher prices. This is because the highest priority user should pay for the congestion he causes in his own priority group and for all priority levels below. Thus, the higher the precedence level, the greater the likelihood that a call made will interrupt or block another call. There are simply more calls than can be blocked when a higher precedence level call is made. The earlier AUTOVON report provides additional discussion on this point.

One could generate some feel for possible price levels to charge different users by using traffic engineering information to determine the effect of additional traffic on the grade of service, for each precedence level. Assumptions could be made concerning relative values of call-seconds in each precedence group to generate hypothetical price structures. As a start, prices could be calculated assuming that all call-seconds have the same value, regardless of precedence. This method would generate a price spread, with flash prices highest.

e. Other Characteristics

In the preceding sections, we discussed in some detail how efficient prices for a variety of services might be calculated. These methods can be used to price other services as well. For example, DCA might want to charge more for calls made during

busy hours. One can see that it is efficient to charge a higher price for calls made during peak hours (or offer a discount for calls made during off-peak hours), since the congestion toll (discussed above) would be greater when there is more traffic. Other characteristics which are fairly easy to price are truncated dialing, notification when circuit is down, and encrypted communications, since the cost of providing these specific services can be identified and charged to the user.

The method used in the preceding sections generated a price per unit of communications service such as a call-second. But if the required information on traffic is not available, or if users are not charged in these units, the cost can be converted into other units. For example, price can be adjusted to a dollars per hour figure by simply estimating the users' expected traffic during this period.

In general, a service with any kind of feature can be priced using the method described above. Whenever possible, cost savings due to economies of scale or any other reason should be passed on to the user of that particular service, to preserve the efficiency and rationing ability of the price structure.

f. Cream-Skimming

In order to better understand the advantages to be gained by passing cost savings on to the customer, suppose that the price of all service was set equal to the average cost per second for a particular transmission capability. Suppose also that service between two points could actually be provided more cheaply than the average (e.g., due to greater traffic volume or geographic considerations). If service between those points is available from other sources, and priced to reflect the lower costs, the users will have an incentive to purchase

services elsewhere. But in those cases where the cost of providing services lies above the average, users will stay with DCS services. This will cause the average price to rise over time as low-cost users leave the system. This is the cream-skimming phenomenon faced by a service provided on a network (mail, trucking, etc.).

Even if cream-skimming were prohibited, this gross averaging method weakens the rationing power of prices and gives wrong information to users concerning the cost to the government of a service. Suppose, for example, that the user was not given the choice to go outside the DCS to get the cheaper service. If the price was equal to the average call-second cost, users would tend to buy *more* of the expensive (to produce) service than warranted and *less* of the cheaper service than warranted.

g. Interim Pricing Problems

In the preceding section, we described how one might derive a price per call-second for the existing grade of service. If the grade of service is not the grade of service desired by DCA for the existing volume of traffic (that is, the total capacity is not at the optimal level), then dividing total cost by the current traffic volume is incorrect. Instead, the amount of call-seconds that can be accommodated by the network at the targeted grade of service should be used. If the network size is smaller than the desired level and if DCA expects to be able to generate the traffic consistent with the optimal network size, then the cost of the optimal network size should be divided by the amount of traffic that this network can handle at the targeted grade of service.

The relation between prices, network capacity, and grade of service implied in the preceding paragraphs warrants additional discussion. The organization which provides

communications service on a network can choose two out of the three variables. The third is then determined. For example, suppose DCA or DoD fixes the size of the AUTOVON network and DCA sets the price. The grade of service is then determined by the number of users who decide to subscribe and the amount of traffic they generate.

A similar problem, applicable to all systems, is the question of how to price service when existing capacity is not optimally configured. This may be due to the fact that old or high-cost transmission equipment is being replaced by lower-cost equipment, but the replacement process is not complete. The volume and geographic location of traffic may be changing as well as the needs of customers. Note that this situation is encountered by any business which is faced with changes in production methods and user demands, and occurs because capital cannot be adjusted instantaneously (at zero cost) to accommodate the changing conditions.

If economies of scale and other cost savings (due to better equipment) are to be passed on to the customer, the costs of the new equipment should be used. This use of planned costs rather than actual costs is a much riskier method of pricing since the expected volume of traffic may not materialize and cost estimates may be incorrect. The latter method does have the advantage that economies of scale can be offered to potential users of a system to encourage their use of the system. A cautious blending of the two approaches is one way of avoiding the risk and reaping some of the benefits of the second approach.

C. RESPONSIBILITY FOR DCS PROCUREMENT FUNDING

In CONUS, virtually all switches, trunks, and other capital equipment are leased from commercial suppliers and paid for through the industrial fund. Overseas, however, the

the situation is much different. Nearly all switches, a large number of trunks and practically all other capital equipment is owned by the US Government, having been purchased by one or the other defense agencies through its procurement budget. It is arguable that, if the procurement functions were centralized in DCA, the configuration of the government-owned networks and the composition of the stock of capital equipment might be more nearly optimal that it is at present.

The current, de-centralized procurement system can result in two types of problems, as discussed above:

- Military departments responsible for funding procurement in a particular area may not be responsive to the needs of other military departments and defense agencies.
- De-centralized procurement can lead to increased government costs, by inhibiting coordination and system design for the various DCS facilities.

On the other hand, centralization at DCA of responsibility for funding DCS procurement could lead to problems of its own:

- Military departments would lose control over DCS services they provide to themselves, the ability to include non-transmission economic considerations in the design of facilities, and the flexibility to reprogram procurement funds to meet unplanned requirements.
- DCA would escape much of the pressure to do its homework and to sell its procurement proposals which is inherent in the present de-centralized system.

While anecdotes are available to support each of these potential problems, it is very difficult to measure the associated economic costs. The present planning process inherent in the FYP includes checks and balances which tend to prevent any of these problems from becoming too serious, but could also be adapted to work under centralized procurement as well.

1. Pricing and Procurement

The question of the desirability of centralization of procurement is also bound up with decisions concerning the allocation of capital costs. Under the present system, capital costs are not included in DCS subscriber charges. If a full-cost pricing system were instituted, it would be necessary to maintain centralized accounts for all capital expenditures (no matter who paid for them) and to include depreciation for capital assets as one of the costs to be covered by subscriber charges. That portion of the revenue that was equal to the annual depreciation would then need to be accounted for within the CSIF. DECCO would have either to allocate the revenue to the entities that had orginally made the expenditures or to retain it in the fund to be applied against new expenditures if procurement were centralized.

If the present system of procurement by individual agencies were maintained, these agencies would need to be credited with an amount equal to the depreciation on the stock of assets they had purchased in years past. These credits could be applied against their bill for services supplied by DCA, or they could be added to their procurement budget, or they could simply enter into their overall budget calculations as a source of funds.

If procurement were to be continued by individual agencies, however, and the funds generated by depreciation returned to them, there would be a large amount of duplication of accounting estimates. Full accounts for the entire system would need to be kept by DCA. In addition, each agency would need to maintain an account record of capital expenditures and depreciation balances. Agency budgeting procedures might also become more complicated, since the refunds they received from DCA would need to be accounted for in the calculations of budgetary requirements.

These accounting and budgetary problems would be considerably reduced if procurement were centralized and capital equipment were purchased through the CSIF. That portion of user charge revenue equal to depreciation could simply be retained within the fund and applied to the new procurement budget each year.

2. Summary

Whether DCS procurement funding should be centralized ultimately hinges on whether the problems caused by the current system are more serious than those that would result from centralization. But it should be observed that the procurement question is at the heart of the problem of providing services on government-owned facilities. If it is decided that such services are seriously unresponsive to user needs, then the solution should include centralization of procurement. Also practical considerations in the implementation of full-cost pricing may also favor centralizing procurement.

Chapter V

RECOMMENDATIONS AND CONCLUSIONS

A. RECOMMENDATIONS

Based on the analysis outlined above, we have made a number of recommendations and observations. Earlier audits and studies done by the GAO and others have pointed out inefficiencies in the operations of the DCS and recommendations have been directed at removing them. In most cases, however, they have suggested that the preferred solution is more control by DCA over the decisions made by agencies. They have tended to ignore the effects that incentives might have upon the decision-making process and, in turn, upon the efficiency with which services are selected and provided. Our recommendations, on the other hand, have as their central objectives the dissemination of knowledge about the costs of providing service and the creation of incentives to which decision-makers can respond. We believe that if efficiency is to be improved, it must occur with the active participation and agreement of users. It is unlikely that this can be accomplished simply by taking away the users' decision-making powers. Finally, although some of these proposals may have important non-economic effects, those effects are outside the scope of this study and we do not take them into account.

B. PRICING AND DEFINITION OF SERVICES

1. Private-Line Service on Common-User Networks

The major manifestation of inefficiency that DCA must contend with currently is controlling what appears to be a

proliferation of dedicated circuits. In order to do so effectively, however, DCA must recognize that a large part of this problem arises because many users perceive the price/service combinations provided by dedicated circuits to be preferable to those offered by common-user networks. The economically efficient solution to this problem is unlikely to involve simply limiting the number of dedicated lines authorized, but rather improving the price/service combinations offered on common-user networks. To do this DCA must determine accurately when a dedicated circuit is more expensive than a common-user alternative and convince the subscriber he is at least as well off with the common-user service as he is with the dedicated circuit. Achieving this goal will require a number of steps. First, DCA must define and assure itself of the technological feasibility of a private-line service on the common-user networks which duplicates the service offered by a dedicated circuit. Second, it must develop a methodology for accurately computing the total costs of both alternatives--dedicated circuits and common-user private-line service. Third, it must create a charging system that will translate those costs into the prices that subscribers pay in order that they face the true costs of services they buy. If these steps are accomplished, future choices between dedicated circuits and common-user network services can be based on correct information about economic costs.

The steps have different implications for AUTOVON and AUTODIN. AUTOVON is currently used at full capacity. The calculated cost of providing private-line service must include the cost of expanding that capacity. AUTODIN, on the other hand, has excess capacity. This means there is some flexibility in the pricing of service on AUTODIN and the prices could be set so as to increase utilization of present capacity while generating revenue to help cover the fixed cost.

2. Development of an Inventory of Dedicated Circuits

Once a private-line, common-user service is developed and a methodology chosen for pricing it, subscribers should find it an easy task to compare its cost to that of each new dedicated circuit proposed. Inertia or other factors, however, may prevent subscribers from making the same comparison for each of their current dedicated circuits. DCA can aid subscribers as well as increase its own managerial capability by creating an inventory of dedicated circuits and their costs. Part of the information for each dedicated circuit or network should include specification of the characteristics and costs of the common-user network that could be used as an alternative. Costs can be compared in order to determine which of the current dedicated circuits are logical candidates for replacement by common-user services.

3. Usage-Sensitive Pricing

Economic efficiency requires that subscriber charges differ when and to the extent that the costs of providing the respective services differ. Subsidizing one subscriber at the expense of another produces incentives which cause users to behave inefficiently. Such subsidization almost invariably occurs when costs are averaged to obtain user charges which are fixed and independent of usage. Subscriber charges for the common-user, switched systems should depend not only on connectivity but also on factors such as the amount, duration, distance, direction, timing, and precedence of usage, all of which affect costs.

The charges should be assessed at the level of the communications commands of the military departments, providing incentives to configure requirements so as to minimize government costs of satisfying user needs. The communications commands, in turn, may provide at their discretion incentives to

operational commands to evaluate and restrict the calls or messages of individual users. Individual users could be controlled by means of PBX service restrictions and/or administrative procedures. While the individual user need not be billed, information on his specific calls would be available.

Adoption of usage-sensitive pricing would lead not only to more efficient use of the common-user system but also would help reduce dependence on dedicated circuits since it effectively permits subscribers to tailor the services they pay for and consume more closely to their needs. Due to the long-term nature of the investments involved, however subscriber charges should provide long-term planning guidance and thus should not fluctuate in response to temporary conditions of excess capacity or congestion.

4. Installation of AMA Equipment

Information is currently generated which would permit usage-sensitive pricing to be adopted on the AUTODIN system. AUTOVON, on the other hand, would require the installation of Automatic Message Accounting (AMA) capacity throughout. Whether it is worth the cost of installing such equipment now could be determined only by comparing its cost (at present an unknown) with the benefits of what it might accomplish. We do strongly recommend, however, that any new equipment installed in the DCS include AMA capacity and that it be put into operation as soon as feasible. The information generated by AMA would be useful not only for billing purposes but also as an extremely valuable management tool for DCA.

5. Restricted Services

As a less flexible alternative or adjunct to the above proposal on usage-sensitive pricing, the common-user switched networks could offer services which restrict network access

more narrowly than at present. Community-of-interest restrictions could include smaller calling areas, calling areas defined in terms of distance bands (like WATS), or specification of the particular numbers a subscriber could call. Time restrictions could include allowing access only during certain pre-arranged periods, such as non-busy hours or particular hours during the business day. Subscriber charges would reflect differences in the government costs of providing the various services. Restricted services, therefore, would provide better incentives for subscribers to consider the effect of the distance and timing of calls on government costs. Further, restricted services would reduce the availability of the networks for unjustified calls, since subscribers would acquire services more closely tailored to their legitimate needs. Implementing restricted services would require software and/or hardware changes at the network switches.

6. New Common-User Services

In addition to the provision of private-line services on common-user networks, DCA should consider developing and implementing some new alternative services for its subscribers. This study has not determined the feasibility of particular new services, but examples of the types of services which should be considered include:

- Administrative precedence or guaranteed grade of service, provided without command-and-control justification to subscribers willing to pay incremental cost (on AUTOVON or AUTODIN, permanent or peacetime only, assuming no degradation of service to other users or interference with command-and-control requirements);
- Data-conditioned AUTOVON trunks for data and secure-voice transmission;
- Off-peak wideband service, using AUTOVON voice trunks;
- Combinations of these services with particular community-of-interest and time-of-day considerations.

C. FULL-COST PRICING

1. Inclusion of All Economic Costs

Charges for DCS systems should reflect the relative economic costs of the services provided. The present practice of excluding overhead (other than DECCO), military personnel costs, and depreciation expense on government-furnished equipment results in serious distortions. Systems furnished mainly by commercial lease contracts have subscriber charges which reflect most of the economic costs. There are no subscriber charges, however, for services furnished entirely by government-owned equipment. Such discrepancies provide incentives for subscribers to choose systems with low subscriber charges rather than low economic costs to the government. Accordingly, DCA should consider adopting subscriber charges for all DCS services and these charges should reflect all economic costs (including overhead, military personnel, and depreciation on government-furnished equipment).

2. Accounting Procedures

Practical management considerations should dictate the way in which depreciation, military personnel expense, and overhead are incorporated into subscriber charges to achieve full-cost pricing and the way in which cash flows from subscribers are channeled into various budgets. There are at least two possible ways this can be accomplished:

- Costs could be reimbursed by the CSIF to the military departments which currently fund them, perhaps as a credit against their subscriber charges for using DCS services.
- CSIF funding could be extended to additional items (e.g., procurement), and the associated outlays recovered by subscriber charges.

The second alternative would certainly be less complicated from an accounting and budgetary point of view. But the first

alternative also appears feasible, so that full-cost pricing does not necessarily imply centralized funding of procurement and other costs.

D. FUNDING PROCUREMENT

The present, decentralized method of funding DCS procurement is inefficient in two respects:

- Military departments responsible for funding procurement in particular areas cannot always be responsive to the needs of other military departments and defense agencies;
- Decentralized procurement increases government costs by inhibiting coordination and system design for DCS facilities.

But centralization at DCA of responsibility for funding DCS procurement would lead to other problems:

- Centralization would reduce the present ability of military departments to be responsive to their own needs;
- DCA would face less pressure to properly justify its procurement proposals.

It is difficult to measure the economic costs associated with decentralization of procurement funding, or to predict those associated with centralized funding. In principle, the checks and balances inherent in the present system could prevent any serious problems. To the extent that inadequate coordination leads to higher government costs, the problem might be solved by better procedures. But, if lack of responsiveness to needs between military departments is a serious problem, then centralization of procurement funding is almost certainly a part of the solution.

E. ADDITIONAL OBSERVATIONS

1. Military Budget Incentives

While this study does not make recommendations regarding internal military department procedures, certain observations are in order:

(1) DCA has a profound influence on the efficiency of military requirements decisions, by virtue of the way DCA defines services and designs subscriber charges.

(2) Efficiency might be served if major commands were given additional fiscal responsibility for communications decisions. With usage-sensitive pricing, for example, the major command could be allocated (by the communications command) a dollar limit for common-user services, and be permitted to choose the amount of usage and number of access lines within that limit.

(3) Budget incentives to minimize costs are not always influential at the stage where military departments design and validate requirements. It may be too late to re-design requirements at the stage where budget requests are allocated.

2. AUTOVON Queues

Valuable time is lost re-dialing AUTOVON call-attempts due to congestion on access lines and on the AUTOVON backbone. Automatic or manual procedures should be studied, to permit users to attempt calls once and then be notified when an appropriate circuit is available.

3. Selling DCS Service

Some alternative methods of operation could deliberately reduce the user's freedom to select among DCS systems. For example, services could be defined in terms of characteristics of user needs rather than the technological means of supplying them. DCA would have the authority to decide how the required services would be provided. Proponents of such a system would presumably contend that the added coordination and

centralization provided by it would allow DCA to more efficiently provide services.

Such a system would have important drawbacks:

(1) Users would have less ability to assure that their service needs were met;

(2) DCA would lose efficiency incentives which result from the limited amount of price competition which now exists;

(3) If subscriber charges failed to reflect economic costs for particular services, users would not be able to base requirements decisions on economic costs to the government.

Following the policies recommended above (especially under A and B), desired efficiency within the existing administrative framework would be achieved and these drawbacks would not be suffered.

APPENDIX A

SUMMARY OF PREVIOUS AUDITS OF THE DCS

SUMMARY OF PREVIOUS AUDITS OF THE DCS

In this appendix we summarize audits of the DCS made by various agencies including the General Accounting Office (GAO), the Defense Audit Service and the Office of the Assistant Secretary of Defense (Comptroller). Since these audits were carried out between 1970 and 1978, many of the recommendations made have already been acted upon by DCA and the military departments.

The first section of this appendix is composed of very brief abstracts of the audits with emphasis on the recommendations made. The abstracts in the second section are somewhat longer and summarize the findings of these same audits. In both sections the summaries are arranged chronologically.

A. ABSTRACTS OF AUDIT RECOMMENDATIONS

1. Auditor General, Comptroller of the Air Force, "Management of the Automatic Digital Network (AUTODIN)," December 18, 1970 (page A-10)[1]

In this study of AUTODIN switching centers it was found that there was considerable excess capacity in automatic switching centers; therefore, it was recommended that the Air Force headquarters:

- Identify and eliminate high cost tributaries, excess cryptographic equipment and reduce manpower accordingly.
- Require that Requests for New Service include traffic estimates.

[1] Page references in parentheses refer to the placement within this Appendix of detailed summaries of these audits.

- Establish procedures to inventory equipment and conduct utilization surveys.

2. <u>OASD Comptroller, "Report on the Audit of Special Construction Contracts, Defense Commercial Communications Office," May 13, 1971</u> (page A-11)

This audit suggests that DECCO negotiators and contracting officers could be more aggressive in getting lower prices for special projects and in settling terminations. Accordingly, it was recommended that:

- Increased emphasis be placed on analyzing the proposed cost of a project carefully before the award is made. Detailed cost analyses should be included with proposals and DECCO rate specialists and DCAA auditors should be used.
- DECCO establish a policy concerning the settling of terminations.
- DECCO reassess the use made of the Contingent Termination Liability Report to determine if it is needed and to route it to those who would find it more useful.

3. <u>OASD Comptroller, "Report on the Interservice Audit of the Management of the AUTODIN System," July 9, 1971</u> (page A-12)

The following is a summary of recommendations made to improve management of the AUTODIN system:

- <u>Switching Centers</u>. It was suggested that the operation and maintenance of all AUTODIN switching centers be assigned to one military department. Excess switching centers should be eliminated. There should be a centralized inventory of government-owned switching center equipment and someone assigned the authority to redistribute excess assets.

  DCA should analyze traffic at switching centers and keep records on maintenance hours and costs. DCA's role in the control over center equipment and the devising of uniform personnel standards for switching centers should be clarified so that asset control can be more effective. Also, buying vs. leasing of

equipment should be considered as should all methods of obtaining AUTODIN equipment and services.

- Tributaries and Terminal Equipment. It was suggested that OASD (Telecommunications) assign responsibility to consolidate tributaries. Uniform standards governing tributary operations should be established and periodic reviews made. Control of terminal equipment should be controlled more carefully through inventorying of equipment, review and reallocation of equipment. Maintenance costs can be cut through increased use of principal period maintenance contracts.

- Other. Policy should be established to assure more realistic subscriber forecasts. Also, procedures should be established to refund government for outages of leased equipment. Finally, the role of DCA as manager of AUTODIN should be defined more clearly. DCA should also monitor the training program more closely.

4. GAO, "Benefits from Centralized Management of Leased Communications," Dec. 22, 1971 (page A-16)

In its examination of minor (costing less than $200,000 per year) leased communications services within the continental U.S., GAO recommended that the Secretary of Defense study:

- The feasibility of establishing a central authority which should have: (a) complete information concerning communications facilities, their purpose, and their traffic volume; (b) the authority to review new leasing requests and to choose the most economical method of providing a service; and (c) the responsibility to review existing services in order to eliminate waste and duplication.

- Whether the criteria for reviewing leasing requests be redefined and lowered. Currently, lease requests below $200,000 per year are reviewed by the military departments rather than the Secretary of Defense. Redefining the limit may also be in order since some leases are for one small part of a much larger network of services.

- The need for a requirement that new requests for communications services provide information which would enable the validating office or central authority to choose the most economical method of fulfilling the request.

- The need for the remaining parts of the Military Police Network started in 1967, but incomplete as of this report.

5. <u>OASD, Comptroller, "Report on the Audit of NORAD/ADC Leased Communications Requirements," January 31, 1972</u> (page A-18)

In this study of the Aerospace Defense Command in support of the North American Air Defense Command, it was recommended that NORAD/ADC:

- Study requirements of the Cheyenne Mountain Complex to determine the minimum number of hardened entrances and connections to switching centers.
- Improve management of leased equipment at Region Control Center and Back-up Interception Control locations by: asking DECCO to submit monthly statements detailing equipment leased and then verify the statements; finding out why lease costs of equipment at various locations vary so greatly; having DECCO ask carriers to readjust prices on equipment with fully amortized termination liability; and finding out if excess fully or partly amortized equipment can be substantiated for new equipment.

6. <u>OASD, Comptroller, "Report on the Audit of the TELPAK Division Defense Commercial Communications Office," May 5, 1972</u> (page A-19)

Recommendations are:

- The TELPAK Division should obtain and continuously review information on circuits by location and planned major circuit changes in order to plan reconfigurations to cut costs.
- DECCO should update the agreement with GSA to prorate GSA's shared TELPAK charges on the basis of actual usage and eliminate housekeeping support being furnished to GSA.

7. <u>OASD, Comptroller, "Report on the Audit of AUTOVON Management," June 21, 1972</u> (page A-19)

In order to improve the quality of AUTOVON service, it was recommended that:

- The JCS establish a criteria or ratio of minimum access lines to provide adequate inward grades of service. DCA should be provided the authority to review access lines and enforce the criteria.

- DCA and the military departments work to: develop procedures to recognize and solve AUTOVON problems; reduce excess 4-wire subscribers and unfair precedence assignments; and control AUTOVON user abuse.

- OASD provide DCA with the authority to properly integrate dedicated networks into AUTOVON.

- Traffic statistics be used to identify problems, to help DCA integrate dedicated networks into AUTOVON and to provide information for DCA's programs to purchase capital equipment for the AUTOVON system.

- In addition there were specific cost cutting recommendations such as to: integrate the JCS Alert Network and Air Force Command Post Network into AUTOVON: modify or eliminate DCA's access line performance report; and provide more accurate reporting of circuit outages for refund purposes.

8. <u>GAO, "Reduction of Communications Costs Through Centralized Management of Multiplex Systems," Jan. 18, 1973</u> (page A-21)

GAO studied a number of circuits and concluded that multiplexing (whereby several messages can be sent simultaneously along a single circuit) could reduce communications costs substantially.

These economies of scale can be achieved however, only if departments and agencies (military and civilian) which use circuits between similar locations can combine their requirements to install and use the multiplexed system. Accordingly, the GAO recommended that:

- Departments and agencies identify their communication needs which may be susceptible to multiplexing and that multiplexing be used when economically and operationally feasible.

- Secretary of Defense develop procedures for coordinating civil and non-tactical military communications which may be susceptible to multiplexing.

- Consideration be given to the establishment of a single entity with the authority for the development and management of multiplex systems for the entire government.

GAO felt that without centralized coordination, multiplex systems would not be fully developed within or between military and civil agencies. GAO points out that while some military departments have developed some multiplex systems independently, more could be developed. GAO points out that DCA had proposed additional multiplex systems, but only two out of eight studies by DCA were fully adopted (two others were partially accepted).

9. <u>OASD, Comptroller, "Report on the Interservice Audit of Defense Communications Requirements," March 18, 1974</u> (page A-22)

This report evaluates the management of leased dedicated trans-oceanic circuits and networks and the long-haul communications of selected post, camps, stations and bases. The report concluded that on the basis of their audit, about $6 million per year could be saved by better management of leases. In particular, dedicated circuits and networks can be integrated into common users systems or reconfigured for savings of about $3.3 million per year; more efficient management of multichannel transoceanic circuits and more accurate billing of non-DoD users could cut costs; large telecommunications projects such as Defense Advanced Research Projects Agency needed more control; management of special construction circuits (to put unused ones on standby) could be improved; uniform inventory and record keeping could help lower costs; centralizing the administration of leases would enable one body to develop expertise in leasing and thus prevent excessive lease charges on equipment; and DCA's management of its switched network could be improved to eliminate excess lines.

10. <u>OASD, Comptroller, "Report on the Audit of the Communications Services Industrial Fund," April 9, 1974</u> (page A-25)

The following summarizes recommendations made:

- DCA should work to eliminate uneconomical facilities from the communications services it provides.
- The CSIF charter should be amended to permit purchase of equipment when lease versus buy study indicates that purchase would be more economical.
- In order to manage switching centers more effectively; DCA should: more clearly specify what expenditures for switching centers are reimbursable; and establish procedures for reporting excess manning at switching centers.
- In order to manage cryptographic equipment more effectively, DCA should define responsibilities as well as requirements for maintaining and manning cryptographic equipment. Also, reimbursement for civilian cryptographic personnel should be clearly spelled out.
- Billing procedures should be revised so that: overhead costs are allocated to subscribers based on his share of CSA's managed by DECCO; non-DoD customers reimburse DoD for military personnel services provided; AUTOVON subscribers using similar equipment are billed comparably; and AUTODIN users are billed according to messages sent. In addition, it was recommended that all subscribers be required to submit financial plans and that specifically constructed facilities be amortized over the life of the asset or a period consistent with industry practice rather than four years.

11. <u>GAO, "Need to Consolidate Responsibility for AUTODIN," July 17, 1974</u> (page A-27)

Excess capacity exists in certain areas because individual military departments did not cooperate with each other in establishing systems which would capture economies of scale. This was so even though the Deputy Secretary of Defense earlier directed consolidation of AUTODIN terminals. Accordingly, GAO recommends that:

- The Secretary of Defense designate a single manager for the AUTODIN system and direct this manager to

evaluate the possible consolidation of terminals and automation of centers. (GAO suggests that this manager be DCA).

- Current automation plans be frozen until the manager reviews the plans.

12. <u>GAO, "Why Performance of AUTOVON Service Needs Improvement," September 11, 1974</u> (page A-29)

GAO found that the AUTOVON service in many locations does not meet the inward grades of service objectives set by the JCS due to insufficient inward access lines by subscribers. This low grade of service causes users to make several attempts before completing their call, further tieing up trunk access lines. In order to encourage users to put in an adequate number of inward access lines, and because DCA's previous recommendations to military departments have largely been ignored, DCA has set up a system of prices which can lead to increases in AUTOVON operating costs.

Thus GAO recommends that DoD:

- Give the system manager the authority and resources to balance components of the AUTOVON system (access lines configuration, etc.).
- Prevent changing the AUTOVON rate structure to encourage in access lines since this may cause inefficient access line configuration.

13. <u>OASD, Comptroller, "Report on the Audit of the TELPAK Branch, DECCO," January 13, 1975</u> (page A-31)

In this audit of the Joint TELPAK Management Group (JTMG) and the TELPAK Branch, it was recommended that:

- JTMG be dissolved and GSA become a full subscriber for TELPAK service.
- Billings for TELPAK service be more accurate.
- Computer reports furnished for TELPAK management be revised to provide information that is more useful to the TELPAK Branch.

14. **OASD, Comptroller, "Report on the Audit of Minimum Service Charge Management by DECCO, July 18, 1975** (page A-32)

In order to reduce communications cost by the reallocation of traffic from leased lines to idle Minimum Service Charge (MSC) circuits, it was recommended that:

- Monitoring of minimum service charge circuits be improved to achieve maximum use. It was suggested that TELPAK Branch have this responsibility.
- MSC computer and billing procedures be strengthened so that these circuits can be located and so that customers can be billed more accurately.

15. **DCA, "Feasibility of Financing Additional Resources Through the CSIF," October 23, 1975** (page A-32)

DCA proposed four alternatives for financing DCS capital equipment and some of the operating and maintenance costs (those not currently financed by the CSIF). The four alternatives are:

- To improve existing procedures concerning DCS procurement and operating expenses.
- Allow DCA to control capital purchases through DCA procurement appropriations rather than the military departments' procurement appropriations.
- Finance all DCS operations (maintenance and procurement) through CSIF and
- Finance parts of the DCS operations and procurement through CSIF.

This report discusses the advantages of each alternative and recommends the last alternative, with the second to last alternative as an objective.

16. **GAO, "Better Management of Defense Communications Would Reduce Costs," December 14, 1977** (page A-35)

In this report, GAO recommends that the Secretary of Defense:

- Establish criteria to justify new or continued use of dedicated communications services.

- Establish periodic reevaluations of communications services which include usage studies.
- Give DCA authority and resources to insure that the most effective and economical method of providing new services is used.
- Direct DCA to develop a complete inventory of communication services and facilities.
- Direct DCA to use more fully its authority to consider current dedicated service users when improving performance of existing communication networks or when designing new or expanded common-user networks.

17. **Defense Audit Service, "Report on the Review of Communications Services Industrial Fund," October 25, 1975** (page A-37)

The Defense Audit Service recommends that the CSIF:

- Be used to finance most of DCS capital equipment and operating costs.
- Be expanded in its use as a management tool.

B. ABSTRACTS OF AUDIT REPORTS

1. **Auditor General, Comptroller of the Air Force, "Management of the Automatic Digital Network (AUTODIN)," December 18, 1970**

In this study of AUTODIN, it was recommended that the Air Force headquarters:

- Identify and eliminate high cost tributaries, excess cryptographic equipment and reduce manpower accordingly.
- Require that requests for new service include traffic estimates.
- Establish procedures to inventory equipment and conduct utilization surveys.

These recommendations were made because it was found that Automatic Switching Centers (ASC's) in the continental U.S. were operating at one-third capacity and even less for the overseas centers. Bases with more than one tributary did not make enough of an effort to consolidate their facilities to

lower costs. Eliminating the excess would cut manpower costs to maintain the centers as well.

This report also points out that civilian ASC but not military manpower costs are reimbursed by the CSIF. The Air Force also used more military personnel in the continental U.S. switching centers than the Army or Navy. Thus, of the $11.9 million of CSIF reimbursements made to military departments on operations of the ASC's, the Air Force received thirty-one percent although it operated fifty percent of the ASC's.

The audit pointed out the lack of a cost accounting system for ASC operating costs and reported several cases where costs could be cut without impairing AUTODIN operations. For example, maintenance contracts could be altered to cut costs. The report indicates that the Air Force and DCA have been more concerned with the operational rather than financial aspects of the system.

In addition, the Audit made some specific recommendations such as: to reconsider the Air Force plan to provide AUTODIN tributaries to 38 district offices of the Office of Special Investigations and to eliminate excess cryptographic equipment (and associated manpower) at the AUTODIN ASC's.

2. <u>OASD, Comptroller, "Report on the Audit of Special Construction Contracts, Defense Commercial Communications Office," May 13, 1971</u>

The purpose of this audit was to analyze the efficiency of evaluations performed by DECCO negotiators and contracting officers in negotiating and awarding special construction contracts and in settling terminations. After reviewing files on 16 communications Service Authorizations it was concluded that DECCO negotiators have not been aggressive enough in demanding adequate cost data for cost evaluations. As a result, it was felt that government was not obtaining the best price for

services. The following recommendations were made to correct the situation.

- Analysis of the proposed cost of a project before an award is made should be emphasized. Accordingly, a detailed cost analysis should be included with proposals. Furthermore, DECCO rate specialists and DCAA (Defense Contract Audit Agency) auditors should be used in the preaward evaluations.
- In addition, it was recommended that DECCO establish a procedure for settling terminations. It was suggested that persons involved in settling terminations be different from those involved in the initial negotiation of a contract. Furthermore, it was suggested that DCAA be granted access to records for audit purposes. Even though claims could be settled on the basis of actual cost rather than estimates, it was found that this practice was not always used. Filed estimates were often used in settling terminations. However, although some claims were felt to be excessive, government had no recourse because of limited access to records.
- Finally, it was recommended that DECCO reassess the use made of the Contingent Termination Liability (CTL) Report to determine if it is needed. If it is to be continued, the reports should include all applicable contracts and the office of primary responsibility for the report should be changed form Special Contracts Division to DECCO Budget and Financial Analysis Division. It was found that the report currently contained many discrepancies. Also, the office of primary responsibility found little use for it, although secondary recipients such as the DECCO Budget and Financial Analysis Division found a need for the report.

3. <u>OASD, Comptroller, "Report on the Interservice Audit of the Management of the AUTODIN System," July 9, 1971</u>

The particular concern of this audit was the review of responsibilities and inter-relationships between DCA and the military departments on the equipping, manning and financing of AUTODIN facilities. The following problems were cited:

- Below the Secretary of Defense level, there is no one agency with authority to manage the AUTODIN system. The divided responsibilities between DCA (control over

switching centers and trunks) and the military departments (control over subscriber terminals) creates problems.

- Overestimates of expected number of subscribers have caused excess capacity and inaccurate subscriber rates.
- Control over equipment costs at switching centers is weak, resulting in the existence of unneeded equipment and maintenance personnel and more costly configuration of equipment.
- Control over AUTODIN tributaries was not effective, resulting in excess tributaries, more expensive equipment than warranted, more expensive maintenance contracts than necessary, etc.
- Procedures have not been established to assure that government receives full refund for interrupted service due to equipment outages.
- Studies and reports obtained from Western Union costing $7.8 million since 1966 were not being used much.

Currently, AUTODIN tributaries are not considered part of DCS and are the responsibility of the military department or agency. Thus there is no centralized inventory control over subscriber terminal equipment. Responsibility over management of access lines from tributaries to switching centers are not clearly defined. Switching center management is divided among the military departments which operate the centers and DCA which is supposed to manage them. This divided responsibility causes many problems according to this audit.

DCA officials and DOD personnel participate in two management groups but this committee type management has not been effective in resolving problems.

It was recommended that the Assistant to the Secretary of Defense (Telecommunications):

- Consider assigning operation and maintenance of all AUTODIN switching centers to one military department, probably the Air Force, since it currently operates 10 out of 20 centers. In addition, this report made other suggestions aimed at strengthening switching center management such as the establishment of a

centralized inventory of government-owned switching center equipment and the assignment of authority to redistribute excess assets.

- Explore all methods of obtaining new equipment and service for AUTODIN switching centers competitively. Buying as opposed to leasing equipment should be considered.

- Emphasize to the military departments DCA's role in the control over center equipment. This would help DCA's attempts to get reports of excess equipment from the military departments. In addition, DCA in this role should strengthen asset control procedures in order to reallocate or eliminate excess equipment and lower costs.

- Provide guidance necessary to determine cryptographic requirements at switching centers. DCA's authority (or lack thereof) over switching centers and the military departments has resulted in an excess of equipment and personnel.

- Have DCA establish control over maintenance hours spent on switching centers. This would include keeping records on maintenance hours and determining reasons for significant differences in maintenance hours (and costs) of similar equipment.

- Clearly define DCA's role in devising uniform personnel standards for switching centers and for determining which costs will be reimbursed by CSIF. Military departments should be required to maintain adequate cost records, especially for reimbursable costs. Finally, DCA should find out why switching center costs vary so widely.

  It was also found that some military departments were reimbursed for some expenses that were never incurred.

- Have DCA establish procedures so that adequate system and traffic analyses are made. Also the operational evaluation teams sould include personnel with financial and managerial experience so they will be able to identify and report problems at switching centers such as excess equipment. This report suggests that the divisions in DCA which should determine where costs can be cut or where more efficient service can be provided were not effective.

- In order to achieve economical tributary operations, the OASD(T) should obtain a list of tributaries that are candidates for consolidation, assign responsibility for the consolidation and assist when necessary. In addition, new service requests should be

subject to more critical review and uniform standards governing the tributary operations should be established. Also periodic reviews of tributary operations should be made.

- Improved control of the tributary procurement procedure is needed to insure that terminal equipment is obtained at least cost. This report recommends that a centralized inventory of terminals be established, that analysis to determine optimum purchase time be made and that AUTODIN terminals be bought or leased competitively.

- Digital subscribers terminal equipment (AUTODIN endpoint equipment) should be managed better. This would involve establishing and controlling inventory, reviewing facilities, reallocating equipment when needed.

- Automatic data processing equipment also should be controlled more carefully to prevent excess equipment. Specific responsibility should be designated in order to accomplish the above and to make lease versus buy decisions.

- In order to cut maintenance costs, principal period maintenance contracts should be used, especially where there are extra terminals available. In addition, new leases should have principal period maintenance options as well as price quotes for principal period and 24 hour service so the marginal cost of the 24 hour contract can be easily determined.

- DCA should consider elimination of several switching centers. The report concludes that excess AUTODIN capacity exists.

- Policy should be established to assure more realistic subscriber forecasts and limit the ability of the military departments to reprogram any excess funds budgeted to AUTODIN. This recommendation was made in order to reduce CSIF losses. Subscriber rates are set (by DCA) on the basis of the military departments' estimates of subscribers. When the estimated number of subscribers failed to materialize the CSIF does not recover backbone costs. The report suggests that DCA should reduce backbone costs and analyze more carefully the inflated subscriber estimates. Since the military departments can reprogram funds budgeted for AUTODIN but not used, there is little incentive for them to be conservative in their subscriber estimates.

- The role of DCA as manager of AUTODIN should be more clearly defined. In addition, DCA should monitor the

training program more closely. Currently, responsibility for personnel lies with the military departments, while DCA is supposed to set standards and manage military department training. In fact, DCA has little control resulting in a shortage of trained maintenance personnel for AUTODIN switching centers.

- Procedures should be established enabling government to be refunded for outage of leased equipment. This would involve a clarification of refunds allowed.
- DCA should consider terminating engineering service contracts with Western Union. It was found that over a period of five years, $7.84 million was spent on these services. Little use was being made of the products delivered because they are too outdated to be of use to management. In many cases the work involves the compilation of government furnished data.

4. GAO, "Benefits From Centralized Management of Leased Communications Services" December 22, 1971

GAO examined the use and control of minor leased communications services within the continental U.S. A minor service is defined as one which costs less than $200,000 per year to lease. About 79 percent of the 236 million DOD spends annually on leased communications services is spent on minor leases.

The GAO recommended that the Secretary of Defense study the feasibility of:

- Establishing a central "activity" with authority to review new leasing requests and select means of providing new service, once the new service has been approved.
- Providing the central activity information on communications facilities available and their purpose and traffic volume.
- Giving the central activity the responsibility to monitor and periodically review the existing services to determine if changes should be made in the method of providing services.

[illegible] recommendations were made because GAO feels that [illegible] with complete information on communications [illegible] their use would be able to provide lower cost

new services and prevent the start or continuation of "uneconomical" services. Currently there is no complete inventory of DoD communications facilities and usage information is often unreliable or unavailable. Furthermore, since the Secretary of Defense reviews and approves services costing more than $200,000 per year, those minor services costing less than $200,000 per year are reviewed by validation offices in each DoD component. These validation offices may not have complete information on existing systems. Furthermore, GAO contents that the Army and Air Force validation offices can only make recommendations concerning alternative methods of providing a service. Evaluations of existing resources are not always made, and when done, are often made by users. The GAO also recommended that the Secretary of Defense study:

- Whether the criteria in reviewing communications requirements at the Office of the Secretary of Defense or at military levels be revised.
- The criteria for review at department level be lowered.

As stated earlier, most leased services are approved within the military departments without review or approval by the Office of the Secretary of Defense because they do not cost more than $200,000 per year. However, the services often represent an addition to existing communications networks. The actual network costs are thus higher. GAO feels that these full costs should be accounted for. In addition, GAO feels that the $200,000 cutoff figure is high. Since May of 1970, only 55 out of about 50,000 leases were classified as major, according to this $200,000 cutoff rule. Furthermore, GAO pointed out several instances where a whole network (for a specific purpose) was obtained using many minor leases. Each lease totaled less than $200,000, although the network itself may be much higher. For example, the partially completed Army Military Police (Criminal Investigation) Network was set up under 22 different leases, but the total leasing costs

exceeded $200,000. The project was thus approved only with the Department of the Army and not the Office of the Secretary of Defense.

The GAO made two additional recommendations:

- Requests For Services provide information necessary for the selection of the most efficient and cheapest method of fulfilling the requests. The user should include information on the purpose of the service, expected traffic volume and related network and terminal equipment involved.
- The Secretary of Defense study the need for the partially complete Military Police Network. GAO feels that because of a lack of centralized management authority, this network has not been completed. In addition, some parts of the system were being discontinued, while others were being installed.

5. Office of the Assistant Secretary of Defense, Comptroller, "Report on the Audit of NORAD/ADC Leased Communications Requirements," January 31, 1972

This is a review of leased communications requirements of NORAD/ADC (Aerospace Defense Command in support of the North American Air Defense Command) which has a 1971 budget of $78 million. The audit concluded that communications costs could be reduced by reevaluating circuit requirements to the Cheyenne Mountain Complex and improving the management of leased equipment at Region Control Center (RCC) and Back-up Interception Control (BUIC) locations. Accordingly, it was recommended that NORAD/ADC:

- Study communications requirements of the Cheyenne Mountain Complex to determine the minimum number of hardened entrances and connections to switching centers there are needed and then test the plan.
- Improve management of leased equipment at RCC and BUIC sites by:
  - Asking DECCO to submit monthly statements detailing the equipment leased and establish procedures to check to see if equipment is actually there.

- Find out why lease costs of equipment at various similar locations vary.
- Have DECCO ask carriers to readjust prices on equipment with fully amortized termination liability.
- Check to see if fully or partly amortized equipment no longer needed can be substituted for new equipment in order to reduce payments of termination liability.

6. <u>Office of the Assistant Secretary of Defense, Comptroller, "Report on the Audit of the TELPAK Division, Defense Commercial Communications Office," May 5, 1972</u>

In this audit, the TELPAK Division was studied as was the 1963 agreement between DECCO and GSA regulating the sharing of TELPAKS by DOD and GSA. Recommendations are that:

- TELPAK Division use summary information on planned major circuit changes and a list of circuits by location and their detour ratios (ratio of circuit mileage to airline mileage) to plan reconfigurations and thus cut costs. Reconfiguration clerks in the TELPAK Division should continuously study the network to determine cheaper ways to reconfigure circuits to use available TELPAK circuits or to shorten routing of individual circuits. Planned circuit changes would allow reconfiguration clerks to plan least cost TELPAK routings from the start. Summary information in circuits would help identify locations that warrant further study for possible reconfiguration.
- DECCO update the agreement with GSA to prorate on the basis of actual usage and to eliminate housekeeping support being furnished GSA by DECCO.

The agreement between DECCO and GSA states that DECCO will provide office space to five GSA personnel and that TELPAK costs will not be adjusted unless the amount of the adjustment exceeds established percentages (2-1/2% on a C TELPAK, 5% on a D TELPAK). Because of this and since DECCO was paying $3,504 per yer to the Air Force for utilities and janitorial service for GSA, DECCO is bearing a large cost for sharing TELPAKS with GSA.

7. <u>Office of the Assistant Secretary of Defense, Comptroller, "Report on the Audit of AUTOVON Management," June 21, 1972</u>

This report concludes that the divided responsibilities for segments of the AUTOVON system have created obstacles to the efficient management of the system and recommends the following:

- The JCS establish a criteria or ratio of minimum access lines to provide P.05 inward grade of service.
- DCA be provided the authority to review access line performance and require subscribers to comply with the criteria mentioned in 1 above.
- DCA and military departments work to: develop procedures to recognize and solve AUTOVON problems; use traffic figures to determine problems; reduce excess four wire subsets and unfair precedence assignments; and control AUTOVON user abuse.
- OASD provide DCA with the authority to properly integrate dedicated networks into AUTOVON. Traffic statistics should be furnished to DCA to accomplish this task.
- DCA's programs to purchase capital equipment for the AUTOVON system be documented with traffic estimates and projected subscriber population.
- DCA review incoming preemption requirements in small exchanges and four-wire subscribers.

In addition, there were several specific cost cutting recommendations:

- DCA and USAF work to complete the integration of the JCS Alert Network and AF Command Post Alert Network into AUTOVON.
- JCS direct CINCPAC to terminate circuit OD34 (between military assistance command, Vietnam and Commander-In Chief, Pacific).
- DCA modify or evaluate its access line performance report.
- DCA Pacific provide better reporting of circuit outages in order to receive refunds from the common carrier.

These recommendations were made because the audit of DCA Western Hemisphere and DCA Pacific found unnecessary expense due to:

- Access lines which were not rehomed to the closest switch.
- Lack of DCA authority to controll access line configuration.
- Excessively long AUTOVON calls.
- Inward grades of service were found to be below standard. During September 1970-May 1971, the audit found inward grades of service above P.20 in 45 exchanges. About 57 percent of the subscribers experienced inward grades of service above P.05. There is no coordinated effort to improve Pacific AUTOVON Service because the military departments use the Joint Overseas Switchboard (which can absorb AUTOVON traffic overflow) and would rather spend money to improve it. Furthermore, CINCPAC is "operationally oriented and primarily concerned with the command and control capability of AUTOVON."
- Significant savings are possible by establishing and carrying out a switch removal program.
- DCA was investing in oversea equipment that may be in excess of future needs since the requests were not supported by forecasts of future subscribers.
- Little effort was made to eliminate four-wire subscribers, resulting in a large number of such subscribers with routine precedence (325). It was felt that many could have used regular AUTOVON service.

8. GAO, "Reduction of Communications Costs Through Centralized Management of Multiplex Systems: Office of Telecommunications Policy, Department of Defense, General Services Administration," January 18, 1973

Multiplexing is a technique whereby electronic devices are placed at the ends of a single circuit, thus allowing the circuit to simultaneously transmit a number of messages. This eliminates the need for numerous long distance circuits between points.

GAO studied the OTP, DoD, and DCA military departments and GSA concerning policies to plan and manage communication facilities in continental U.S.

GAO studied 200 teletype and low speed data circuits and found that by using a multiplex system, communications costs could be reduced by $400,00 per year in these circuits alone.

Although GAO reviewed 200 selected circuits, DoD leases 3,200 circuits similar in type to the ones studies by GAO, many of which may be susceptible to multiplexing. Also, GAO pointed out that the cost of leasing this kind of circuit had increased from 2¢ per mile to 21¢ per mile over the past five years. The savings can occur (using leased or government-owned multiplexers) whenever a multiplexed circuit is less than the cost of all the separate long distance circuits. This may involve several departments using one multiplexed circuit. Despite the apparent cost advantage, federal agencies have made little use of multiplexers in the continental U.S. This may be due to lack of information concerning requirements of other agencies and departments. Since multiplexing, to be cost efficient, usually involves more than two departments or agencies, it might be difficult to develop a multiplex system unless adequate information between agencies were available. GAO thus recommends that:

- Departments and agencies identify their communication needs which may be susceptible to multiplexing and that multiplexing be used when economically and operationally feasible.
- Secretary of Defense develop procedures for coordinating civil and non-tactical military communications which may be susceptible to multiplexing.
- Consideration be given to the establishment of a single entity with the authority for the development and management of multiplex systems for the entire government.

The GAO felt that without centralized coordination, multiplex systems would not be fully developed within or between military and civil agencies. GAO pointed out that while some military departments have developed some multiplex systems independently, more could be developed. GAO pointed out that DCA had proposed additional multiplex systems, but only two out of eight studied by DCA were fully adopted (two others were partially accepted.)

9. **OASD, Comptroller, "Report on the Interservice Audit of Defense Communications Requirements," March 18, 1974**

This audit of the management of leased dedicated transoceanic circuits and networks and long haul communications (between installations as opposed to within installations) of selected posts, camps, stations and bases made the following recommendations:

- A centralized group should be established to terminate or integrate dedicated networks where feasible. This group should maintain inventory records of all dedicated networks and costs, review justifications for continued use of dedicated transoceanic circuits and monitor the integration or elimination of the circuits according to its recommendations.

It was recommended that AUTOVON grade of service be improved since the military departments' cooperation in integrating dedicated circuits depends on DCA's ability to provide adequate grade of service. However, budget constraints on AUTOVON made it difficult to improve grades of service. Budget officials indicated that budgets would continue to be tight until managers make best possible use of the funds that have been approved for the AUTOVON backbone.

- DCA improve management of the voice frequency carrier Telegraph (VFCT) circuits. It was found that billing procedures to non-DoD customers of VFCT were inaccurate (resulting in $55,000 per year loss to DoD) and that costs could be cut by more effectively utilizing VFCT circuits. Furthermore, there is no relation between the funding of VFCT circuits and their use, and thus no incentive for the user to economize. In fact, half of the $4 million per year VFCT costs were for channels allocated to the National Security Agency and DCA, although neither agency funded the channels.
- Improved procedures be developed so that large projects like the Defense Advanced Research Projects Agency (DARPA) network is planned, developed, and reviewed in an orderly fashion. It was also recommended that DCA and DARPA analyze the benefits of retaining the network in DoD or contracting the service out. In addition, the Director of DARPA should reconfigure circuitry to cut costs and to require reimbursement from non-DARPA users of the network.

It was found that the DARPA network was developed without approval of the Director, Telecommunications, Command and Control. Although $18 million was used to develop the network, DARPA was planning to transfer ownership of the network to commercial interests.

- Steps be taken to insure that the military departments better manage special construction circuitry. The departments were not aware that substantial savings could be achieved by placing unused specially constructed circuits on a minimum service charge status. (A minimum service charge is made for specially constructed circuits until construction costs have been recovered. This monthly charge can be reduced if a circuit is not used.)
- Steps be taken to improve management at the installation (base, etc.). Specifically, communications traffic data should be collected and reviewed to determine if facilities are justified; all alternatives including WATS, AUTOVON and long distance should be considered in satisfying communications requirements; DOD's WATS utilization should be improved; a review process by DOD components should be established to enforce JCS rules on communications economy; and record keeping of facilities should be improved in order to insure that carriers' billings are proper and that local management is aware of all equipment.

The report suggests that enforcing JCS policy concerning length and purpose of calls would cut down on traffic. Also it was found that traffic studies were not always made to justify circuits and that alternative methods of providing communications services were not always considered. Improved record keeping and control at installations could result in better utilization of existing facilities.

- DCA/DECCO or a comparable organization be assigned the authority to centrally procure all equipment and telecommunications services for DOD. This organization should also be given the responsibility to administer contracts and Communications Services Authorizations and to maintain records on inventory and costs to the military departments and installations.

Centralization of leasing activities would enable DoD to get uniform and presumably lower cost leases. It was pointed out that different military departments had paid different amounts to lease identical equipment. It was also found that inventories of leased equipment and review of charges were not always made. It was felt that centralized management could simplify record keeping and verification of charges.

- DCA eliminate excess four-wire AUTOVON lines and reduce the number of phones with AUTOVON access. In addition, annual reviews of circuit requirements should be expanded to include AUTODIN and AUTOVON lines.

It was found that DCA did not review its routine AUTOVON service or its headquarters AUTODIN service. Also, 98 percent of phones at DCA headquarters had AUTOVON access while OSD and JCS policy specifies a 40 percent rate.

10. <u>OASD, Comptroller, "Report on the Audit of the Communications Services Industrial Fund," April 9, 1974</u>

The report recommends:

- DCA work to elimiante uneconomical facilities. In addition, DCA should be required to comply with DoD Directive 7410.4, which specifies that costs of underutilized facilities are not to be automatically charged to all subscribers. The costs of retaining necessary excess facilities should be charged to the beneficiary of the facilities. The costs of retaining unnecessary excess facilities should be borne by the managers of the fund to encourage more attention to the termination of uneconomic leases in the future.

This recommendation was made because it is felt that as a monopoly CSIF could charge to recover from subscribers the costs of underutilized facilities. However, it was felt that some underutilized facilities were due to management and should not be charged to customers. Several cases were pointed out where DCA leased equipment which was not needed.

For example, OASD auditors had recommended against activating two AUTOVON switches in 1971. The switches were leased by DCA anyway. DCA is continuing to study the switches although on July 31, 1972, DCA listed these switches as candidates for removal in the study submitted to the JCS. Also the audit report noted that about 1/5 of leased bit buffers for AUTODIN switches could be returned to the common carrier, as could other unneeded equipment.

- The CSIF charter be amended to allow the Fund to purchase capital equipment when lease versus buy study shows purchase to be more economical.

The audit found that a contract with CODEX Corporation for channel packing was not economical. Purchasing two channel packs would have been cheaper.

- DCA publish a directive defining clearly those switching center operating costs which can be reimbursed from the CSIF; establish procedures to report personnel excess at switching centers; and improve management of cryptographic operations by defining responsibilities and requirements for maintaining and manning cryptographic equipment as well as reimbursement policy.

The audit found that in some cases there was excess manning at switching centers and excess cryptographic equipment. The audit also found a lack of uniformity in cryptographic maintenance personnel and inconsistencies concerning what could be reimbursed. For example, in one year the Army and Navy were denied while the Air Force received reimbursement for the same type of expense.

- Billing procedure be revised to be more indicative of the cost of service provided. The auditors estimate that over $530,000 in 1973 was not recovered from non-DOD customers for this reason. Also, AUTODIN costs were not allocated to subscribers on the basis of service provided (e.g., Air Force billed for 45 percent of AUTODIN cost but account for 30 percent of its traffic). The following specific recommendations were made concerning billing.

- Overhead costs should be prorated and billed to each subscriber based on his share of DECCO operating expense (measured by the proportion of Communication Service Authorizations managed and other service provided). Non-DoD customers should be required to reimburse DoD for military personnel service provided.
- AUTOVON subscribers should be billed separately for access lines and preemption capability on non-tariff 260 switches.
- AUTODIN subscribers should be billed according to traffic transmitted in order to recover all applicable costs.
- All subscribers should be required to submit financial plans in order to ensure that the customer can afford the services it ordered.
- Fund Managers should amortize the costs of capital assets over the useful like of the asset. Currently, Fund Managers amortize cost over four years while the telecommunications industry uses ten years.

DCA's response to these suggestions was:

- DCA felt it was impractical to distribute overhead costs on the basis of CSA's managed. Also, charging non-DoD customers for military personnel expense is prohibited by DoD Directive.
- DCA agreed with recommendations 2 and 3.
- DCA stated it does not have the authority to depreciate assets.

11. GAO, "Need to Consolidate Responsibility for Automatic Digital Network (AUTODIN) Terminals, Department of Defense:" B-169857 July 17, 1974

In this report, the GAO recommended that the Secretary of Defense:

- Designate a single manager for the whole AUTODIN system, including terminals
- Direct the manager to evaluate the potential for the consolidation of terminals and the automation of centers and to take necessary implementing action.
- Where automation plans are underway, to direct the manager to freeze further implementation pending his review.

The GAO found that because no single organization in the Department of Defense has authority to plan and manage the whole AUTODIN system, several problems exist:

- Existing and planned communications capabilities exceed requirements in many areas.
- The 1968 plans to consolidate AUTODIN terminals (directed by the Deputy Secretary of Defense) had not been completed. GAO estimates that DoD could save $2.6 million annually in communications center operating costs.
- GAO found that the military departments had developed their own LDMX[1] plans independently rather than coordinating with other departments to capture benefits of economies of scale. Thus LDMX facilities are being developed which are in excess of DoD's requirements in certain locations.

Since past efforts to coordinate communications facilities have not been effective, GAO feels that a single organization with authority and responsibility to manage the entire AUTODIN system including terminals, switches and circuits would enable the DoD to capture the benefits of economies of scale and prevent duplication of services to areas by separate military departments. GAO prefers extension of DCA's authority to cover terminal management. An alternative is to assign a military department the management authority. The Armed Services Subcommittee of the House Committee on Armed Services recommended in 1971 that DCA should be given management responsibilities over the whole defense communications system.

Currently (i.e., 1974), several organizations (listed below) have responsibilities concerning the AUTODIN system, with no one having authority or responsibility over the whole system.

- Director, Telecommunications and Command and Control Systems (TACCS). This is DoD's top communications manager. This position was originally established as the Assistant to the Secretary of Defense for Telecommunications.

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[1]Local Digital Message Exchange.

- Joint Chiefs of Staff
- Defense Communications Agency (DCA). DCA is under JCS in chain of command and is responsible for managing long distance trunks and switches (but *not* terminals and circuits on posts, camps, bases or stations). DCA has no authority over location, type or number of AUTODIN terminals.
- Military departments are responsible for the terminals and circuits on industrial installations:
  - Air Force - Air Force Communication Service
  - Army - U.S. Army Communications Command
  - Navy - Commander, Naval Telecommunications Command

These offices have differing responsibilities. None has total responsibility or authority over its departments communications systems.

12. GAO, "Why Performance of Automatic Voice Network (AUTOVON) Service Needs Improvement: Department of Defense," September 11, 1974

Concerned with improving the performance and reducing the operating costs of AUTOVON, GAO recommended that DoD should:

- Give the system manager the authority and resources to balance the components of the AUTOVON system (access lines, etc.) in order to maximize efficiency of the system subject to quality and funding constraints.
- Prevent distortion of the AUTOVON rate structure which GAO feels is causing inefficient configuration of access lines.

GAO found that of 390 locations in DCA's analysis, 66 percent did not meet the inward grade of service specified by the Joint Chiefs of Staff. Part of the problem is due to too few inward access lines to get traffic off the network. This causes more traffic as users must make several attempts to get a call completed. Because DCA has control over the AUTOVON backbone (switching centers and interswitch trunks) and because its recommendations concerning changes in access lines are largely ignored, DCA has devised an unbalanced rate structure to

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DoD agreed with GAO's proposal concerning the use of the AUTOVON rate structure. However, DoD feels that since AUTOVON's main goal is for command, control and support of combat forces, individual users should maintain control over access lines.

13. <u>OASD, Comptroller, "Report on the Audit of the TELPAK Branch, DECCO," January 13, 1975</u>

This audit reviewed the TELPAK Branch and the Joint TELPAK Management Group (JTMG). The JTMG was organized to administer TELPAK's shared by GSA and DoD and is made up of personnel for each. The audit recommends:

- JTMG be dissolved and GSA become a full customer for TELPAK service.

It was found that the JTMG was receiving (from DECCO) funds in excess of their share of cost incurred. It was felt that DECCO was not being reimbursed by GSA for costs incurred in processing its services. It was recommended that:

- Billings be more accurate. The audit found billings to GSA for TELPAK Service to be inaccurate.
- Computer reports furnished for TELPAK management be revised to provide information that is more useful. For example, the Circuit Detour Ratio Report did not report circuits with a detour ratio less than 2.4.

<u>OASD, Comptroller "Request for Audit Consultant Assistance --Incremental Cost of Bulk Procurement of Communications Services," February 14, 1975 (Attached to January 13, 1975, Audit Report)</u>

The audit reviewed the Incremental Cost Method of bulk procurement of communication services in order to help determine if DECCO should use this approach in evaluating competitive bids.

This is a method of determining the cost of a circuit mile added to the TELPAK network. It could ultimately be used to determine if specialized carrier circuits could be integrated

into the TELPAK network. It was concluded that this method was basically a sound method for measuring the cost of a circuit mile.

14. <u>OASD Comptroller, "Report on the Audit of Minimum Service Charge Management by the Defense Communications Office (DECCO)," July 18, 1975</u>

A minimum service charge (MSC) circuit is a specially constructed circuit. Since there is a monthly charge for these circuits even if they are not used, communications costs can be reduced by reallocating traffic from leased lines to idle MSC circuits. DECCO has the responsibility for monitoring these lines. The following recommendations were made concerning DECCO's management of these circuits.

- Procedures to monitor MSC circuits should be improved to ensure maximum use of these circuits. It was suggested this responsibility be assigned to the TELPAK Branch.
- MSC computer and billing procedures should be strengthened so that MSC circuits can be located and so that customers are billed accurately.

These recommendations were made because auditors found that:

- Lease costs could have been reduced by the rerouting of traffic to available MSC lines.
- Inaccuracies existed in the MSC location listings.
- Because of errors in the computer listings, DECCO had overcharged the Army by $16,872 a year and undercharged the Navy by $41,760 a year.

15. <u>DCA, "Feasibility Study of Financing Additional Resources Through the Communications Services Industrial Fund (CSIF)," October 23, 1975</u>

DCA proposed four alternatives for financing DCS capital equipment and some of the operating and maintenance costs (those not currently financed by the CSIF). The four alternatives are:

(a) to improve existing procedures concerning DCS procurement and operating expenses.

(b) Allow DCA to control capital purchases through DCA procurement appropriations rather than the military departments' procurement appropriations.

(c) Finance all DCS operations (maintenance and procurement) through CSIF.

(d) Finance parts of the DCS operations and procurement through CSIF.

This DCA report discusses the advantages of each alternative and recommends alternative (d), with (c) as an objective. In general, according to DOD policy, CSIF may not be used to purchase capital equipment. The military departments (and other DoD components) and responsible for the funding, installation, operation and maintenance of DCS systems. They individually prepare and justify their budget requests which are then financed through the CSIF. DCA really controls and must justify in its budget only the backbones of switched networks and DECCO (which operates the CSIF) operating expense. However, those facilities requested (and paid) by the DOD components are included in the CSIF budget in order that requirements can be reviewed centrally. The CSIF allocates its backbone costs through pricing of DCS facilities. Thus the military departments may finance (through its appropriation process) equipment used by a wide range of customers.

There are several problems with managing this system:

- There is not sufficient cost data for analysis and evaluation of programs. Consolidation or reconfiguration of DCA facilities as well as analysis of new programs like AUTODIN II and DSCS require data that cut across departmental lines.
- Costs of the DCS are not allocated properly among users, including the non-DoD users. The following costs are not allocated among the users: cost of acquiring capital equipment, military personnel costs and some of DCS operations and maintenance costs. This gives rise to free riders and distorts costs in lease-versus-buy decision making.
- DCA has difficulty in managing the *system* since system requirements are subject to each military department's budget and review process. They focus on department's

programs rather than on system requirements and priorities.

- It is difficult to switch from a buy (procurement) to a lease (operation and maintenance) appropriation. This causes inflexibility in the current system.

a. Alternative a

Alternative a would attempt to solve these problems by giving DCA greater control over DCS funds throughout the Planning, Programming and Budgeting System process. Included in this is a proposal to provide DCA with data. This alternative would not solve the freerider and the lease versus buy problems. Furthermore, the changes in the DCA charter and the establishment of a formal reporting system would be costly.

b. Alternative b

Alternative b would give DCA control over procurement of DCS capital equipment. This would allow DCS to plan (or justify) DCS capital equipment on a systemwide basis. This would not solve the lease versus buy problem and would increase DCS's budget. Also, since DCA would finance requirements for the DoD components, there would be no incentive for the components to limit requests.

c. Alternative c

Alternative c would allow DCS to finance capital and operational and maintenance (O&M) through the CSIF with procurement costs being amortized over the life of the equipment. Capital and O&M costs would be returned via subscriber rates.

This alternative would allow more comprehensive system planning and could eliminate free (and cheap) riders and the lease versus buy problems and provide the necessary cost and usage data necessary for effective management. DCA suggests the use of Interservice Support Agreements (presently used

for AUTOVON & AUTODIN) whereby the operating and maintaining of the system would be done by the military department but paid for by DCA. However, this proposal would cause rates to increase (causing customers to seek other sources), would increase DCA's budget and restrict the military department's scope of activities. This would also require a change of the CSIF charter.

d. Alternative d

Alternative d would initially finance only certain aspects of DCS capital through CSIF as a part of a phased approach to CSIF financing.

16. Comptroller General of the US (GAO), "Better Management of Defense Communications Would Reduce Costs," December 14, 1977

In this report, GAO recommends that the Secretary of Defense:

- Establish criteria to justify new or continued use of dedicated communications services.
- Establish periodic reevaluations of communications services which include usage studies.
- Give DCA authority and resources to insure that the most effective and economical method of providing new services is used.
- Direct DCA to develop a complete inventory of communication services and facilities.
- Direct DCA to use more fully its authority to consider current dedicated service users when improving performance of existing communication networks or when designing new or expanded common user networks.

GAO reviewed about 550 leased dedicated circuits and concluded that many could be elimianted, changed to provide cheaper service or integrated into the common user network.

GAO feels that dedicated services costs (about $112 million in 1977) could be reduced if a central authority could manage

the communications services on a Defense-wide basis. A previous attempt at reducing dedicated networks (the Network Review Panel) was ineffective. Furthermore, some of the funds currently used on dedicated services could be used to upgrade common-user networks.

Although DCA was established to manage DCS assets, its control over the DCS assets is limited. It has no authority over dedicated facilities which have not been designated as DCS assets. It has been unable to obtain sufficient funds to improve common-user services, especially for low-priority users.

Previous GAO reports and Defense Internal Audits recommend that a central authority manage defense communications. But, JCS and Office of the Secretary of Defense have disagreed.

They have felt that the responsibility for reviewing dedicated networks belongs to individual users.

GAO on the other hand, feels that a centralized authority should have the authority to choose the cheapest method of providing services, given total requirements and available facilities. Currently most new requirements are sent by military departments to their validating offices, but users generally specify the method of fulfilling their requirement. The validated requests are then sent to DECCO (Defense Commercial Communications Office) of the DCA which obtains leases generally without analyzing alternative methods of satisfying requirements.

GAO also found that reviews of dedicated services are generally not supported by usage data.

GAO pointed out another problem. DCS has attempted to improve AUTOVON services by requesting funds to provide conference call capabilities and to increase the number of transoceanic interswitch circuits. Both requests were denied. It

was felt that better administrative control over abuse of AUTOVON use (including abuse of the precedence system) should be established instead. GAO feels that in DCA's planning, greater emphasis should be placed on accommodating current users of dedicated services.

DoD's response to this report is that while agreeing with most recommendations, DoD prefers to improve on current practices rather than to change responsibilities for approval and review of communications requests. DoD stated that the military departments are better able to assess their own communications needs.

17. Defense Audit Service, "Report on the Review of Communications Services Industrial Fund," October 25, 1978

The Defense Audit Service recommends that the CSIF:

- Be used to finance most of DCS capital equipment and operating costs, and
- Be expanded in its use as a management tool.

Currently, DCS equipment is financed by appropriations by the military departments. The CSIF is used to finance common-user networks. The CSIF can procure capital equipment currently only through the Fast Payback Program whereby an item costing between $1,000 and $100,000 can be purchased if it reduces operating costs in two years by the amount equal to the acquisition and installation costs. The Defense Audit Service gave the following reasons for its recommendation:

- Government-owned facilities are used in DCS to provide free service to others (an example is the AUTOVON overseas circuits provided by Government-owned transmission systems).
- There will be increased equipment outlays and increased demand for communications services in the future. There is also a need for a mechanism to control increased requests for services. Currently, for example, satellites are placed in service without charge to customer.

- Other audit reports have also pointed out the need for coordinated control and review of communications services.
- Finally, DCA currently plans DCS but the military departments must implement the plan. They may thus choose to not support DCA's total request for funds. In this situation, DCA then cannot really be held accountable for performance of the system.

APPENDIX B

CHARACTERISTICS OF USER NEEDS

CHARACTERISTICS OF USER NEEDS

Well-defined communications needs are multi-dimensional; that is, they are specific with regard to many different aspects of the needed communications service. Some of the important aspects include the form in which information is to be transferred, timing and volume, geographic locations, quality and reliability, survivability, and availability of service when needed. A communications need is specific with regard to what is called for in each of these aspects of the required service. A service which meets all but one of a user's specifications may be a fine product. But it is a different product than what the user needs.

The following discussion of user needs is organized in terms of characteristics which users specify in defining their needs.

A. TRANSMISSION CAPABILITY (LINE-SPEED OR BANDWIDTH)

The Defense Communications System (DCS) provides a long-haul transmission service for military (and other government) communications. With a few exceptions, DCS users convert the information to be communicated into electrical signals, and DCS provides the service of transmitting those signals among users. Thus, the basic DCS transmission services are defined in terms of the technical capabilities required to transmit various signals.

Users, on the other hand, consume communications services on an end-to-end basis. Their needs are defined in terms of the type of information to be transferred, and the way it is to be

used. Such end-use considerations determine the type of signal the user generates, and hence the specific transmission service required from the DCS.

The transmission service provided depends particularly on the technical characteristics of the circuit used to transmit the user's signal. Bandwidth is an important determinant of the amount of information which a signal transmitted on the circuit can carry. Conditioning is an indicator of the amount of distortion (and hence loss of information) which a signal transmitted on the circuit undergoes.

To transmit ordinary voice signals (between telephones), users specify a need for a voice-grade circuit. That specification implies a bandwidth and conditioning level adequate to transmit the voice signal so that it is intelligible to the recipient. Most non-voice signals generated by DCS users are digital (i.e., consist of on/off pulses). The amount of information carried by digital signals is measured in terms of bits (of information transmitted) per second. Accordingly, user needs can be specified in terms of the transmission line-speed (in bits per second) required. That specification implies adequate bandwidth and conditioning level, so that the information can be transmitted without unacceptable error.

Table B-1 lists a number of communications techniques employed by defense users. For each technique, the typical transmission capability required from the DCS is indicated. The lowest line-speed requirements are for telegraph equipment and control signals for mechanical devices. The highest line-speed requirement is for the transmission of color-television signals.

Note also that techniques involving computers cover a wide range of transmission requirements. A capability of 150 bits per second permits a person to send inquiries to a computer as fast as he can type. But the computer's response must be

Table B-1. COMMUNICATIONS TECHNIQUES AND TRANSMISSION REQUIREMENTS

COMMUNICATIONS TECHNIQUE	REQUIRED TRANSMISSION CAPABILITY
Telegraphy	50-150 bits per second
Automatic Meter Reading Data Collection Systems Alarms Control Signals Remote Operation of Switches Remote Control of Machines	Up to 300 bits per second
Access to Time-shared Computer	Up to 9600 bits per second
Alpha-numeric Man-computer Dialogue	2400 - 9600 bits per second
Ordinary Voice	Voice-grade Circuit
Facsimile	Voice-grade Circuit
Computer to Printer or Card Reader	20,000 bits per second
Encrypted Voice	2400 - 50,000 bits per second
Digitized Voice	20,000 - 56,000 bits per second
High-fidelity Music	400,000 bits per second
Computer Tape to Tape or Disk to Disk	1,344,000 bits per second
Picturephone	6,300,000 bits per second
Television	40,000,000 - 92,500,000 bits per second

Source: Based largely on information in Martin, James, *Further Developments in Telecommunications*, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1977.

received at a rate of at least 2400 bits per second, so that reading it is not frustratingly slow for the recipient. And, when the computer communicates with a remote input/output device, 20,000 bits per second may be required in order to utilize the

capabilities of the devices. Finally, if the information is transferred between computer tapes or disks, line-speeds exceeding 1,344,000 bits per second may be required.

B. DELIVERY TIME

Transmission line-speed measures the rate at which a user can transfer information to the DCS. Delivery time measures the elapsed time before that information is received at the intended destination. When the transmission service is provided by a direct circuit to the destination, the delivery time depends on the amount of information to be transferred, on the line-speed capability, and on the geographic distance to the destination.

But when the transmission service is provided by a message-switching network, additional delays are introduced. For one thing, it takes time to switch information from circuit to circuit enroute to the destination. Even more important, when the network is congested, information may be stored temporarily at the various switches. Since these delays materially affect the character of the transmission, an explicit measure of delivery time (e.g., the "speed of service" on AUTODIN) is used to evaluate the service on message-switching networks.

The need for different levels of delivery time will be discussed below, after the concept of availability is introduced.

C. AVAILABILITY OF SERVICE

1. Definition

The basic character of transmission service is described by the notions of transmission capability and delivery time. The conditions of access constitute another important aspect of transmission service. In particular, is the service available when the user needs it?

There are a number of different availability characteristics to consider. Even under normal conditions, DCS facilities become congested, so that users endure some delay before they can use a DCS transmission service. A common measure of this delay is the grade of service, which is the probability that a request for service will be blocked. Other measures of availability include average or maximum waiting times.

Extreme cases of service delay occur when technical failure or hostile action cause transmission facilities to break down. The likelihood of such breakdown is often an important characteristic of transmission service. This aspect of service quality is measured by the extent to which the transmission technology and facilities are reliable, redundant, and survivable.

Other special features affecting access to the transmission service are important to particular users. Off-hook service automatically connects a user to a particular destination, saving the time of dialing and the chance of mis-dialing during an emergency. Truncated dialing similarly saves time by reducing the number of digits which must be dialed to reach certain destinations. Users may need to be alerted when transmission service breaks down, even though it is not being used at the time. Users may also be sensitive to the time required by formal procedures required to gain access to a transmission service.

2. The Need for Availability

User needs vary with regard to the availability, and the delivery time, of transmission service. The major determinants of needs in these respects are the importance of the information to be transferred, and the efficiency of the user activities which depend on transmission service.

The importance of defense information, of course, is evaluated in terms of the contribution it makes to the security of the United States and its allies. One way of judging that

contribution is to consider the purpose of transferring the information. The most important purpose is command and control, or the direction of combat operations. Intelligence communications are also judged to be very important. Other communications which support combat operations or which are essential to combat readiness are important. Administrative purposes are generally considered the least important.

Another guide to evaluating the importance of information is the set of communications precedence criteria established by the Joint Chiefs of Staff. Top (flash) precedence is reserved for communications directly related to national survival or active hostilities. The next level of precedence (immediate) is reserved for communications which gravely affect national security. The next level (priority) is used for communications requiring expeditious action. The lowest level (routine) is for communications which do not require preferential handling.

When the information to be transferred is both critically important and needed quickly, communications needs are defined in a very exacting way. Transmission service must be available without delay. The probability of the user being blocked from the service, or of the transmission facilities being inoperable, must be virtually zero. Similarly, the delivery time must be quite short, so that the information arrives at the destination in time for the needed action. In other cases, the information may not be needed at the destination immediately, so that some amount of delay is acceptable. Or the information transfer may support a less important mission, so that the cost of the best level of service is not justified.

Operational efficiency may also lead users to define their needs for transmission services in a very exacting way. This can especially be the case where computer applications are involved. By employing computer-related technology, an activity may perform its mission at lower cost, making funds

available for other missions. But efficient utilization of computer equipment may require quick access to transmission services with high end-to-end line-speed capabilities. Thus, efficiency considerations may justify a higher quality transmission service than the importance of the mission would otherwise indicate.

A central problem in planning for user communications needs is the contingency nature of most high-priority requirements. Users define their needs so that transmission services are adequate to handle requirements during periods of crisis. At the same time they provide for (usually different) needs during non-emergency periods, and for low-priority needs during emergency periods.

D. COMMUNITY OF INTEREST

The community of interest for a particular user is the set of destinations with which that user needs to communicate. The dimensions of the community of interest depend on the user's mission and vary greatly among users. The set of correspondents in the community may be stable, or may vary over time. There may be many or few correspondents. They may be concentrated within small geographic areas, or else widely dispersed. Distances among correspondents may be small or long. Correspondents may be located in the same country, or in different countries and continents. The community may parallel other defense communities, or may be relatively isolated.

Correspondents within a community of interest may be located at defense, other government, or private facilities. Communities may also vary with regard to the compatibility of user terminal equipment and software. The community of interest for incoming information may differ from that for outgoing information. Information transferred to each correspondent may be unique, or there may be requirements for conferencing, or for multiple deliveries of the same information. And most important,

the amount of information traffic to particular correspondents may vary considerably.

All of these considerations affect the cost of obtaining the needed transmission service. Closely related is the existing configuration of services for each correspondent. These correspondents may be located on bases with large communications centers offering a variety of services, or in a situation where they must provide for their own services. Correspondents may also be partially interconnected for other purposes.

E. TIMING AND AMOUNT OF USE

User needs also vary with regard to the time pattern of the use of transmission services. The need to transfer information may vary with regard to frequency, predictability, volume, and permanence. The need may be constant day and night, or concentrated within busy or non-busy periods. Particularly important is the variation mentioned above between needs during periods of crisis and non-crisis.

F. OTHER FEATURES

The categories discussed above encompass most of the characteristics relevant to defining user needs. Of course, there are some needs which do not quite fit into these categories. For example, users may require that their information be encrypted for transmission.

Table B-2 summarizes the service characteristics discussed above.

Table B-2. CHARACTERISTICS OF USER NEEDS

Transmission Capability: • Line-speed or Bandwidth • Conditioning Transmission Duration: • Speed of Service Availability of Service: • Grade of Service • Waiting Time • Technical Reliability • Redundancy • Survivability • Off-hook Service • Truncated Dialing • Notification When Circuit is Down Community of Interest: • Stability of Community Over Time • Number of Correspondents • Geographic Concentration of Correspondents • Distances among Correspondents • International Location of Correspondents • Proximity of Other Defense Communities of Interest • Affiliation of Correspondent Location (Defense, Other Government, Private) • Compatibility of Equipment and Software • Coincidence of Inward and Outward Correspondents • Need for Conferencing or Muliple Addressing • Traffic Volume to Various Correspondents • Configuration of Existing Services within Community Timing and Amount of Use: • Time Pattern • Frequency • Predictability • Permanence • Contingency Requirements • Volume Other Features: • Encryption

APPENDIX C

APPROVAL AND FUNDING PROCEDURES OF MILITARY DEPARTMENTS

APPROVAL AND FUNDING PROCEDURES OF MILITARY DEPARTMENTS

As customers, the military departments play a pivotal role in determining the efficiency of the Defense Communications System. Accordingly, this Appendix is included to provide additional information on the internal approval and funding procedures followed by the military departments.

Within each military department, a user's need to transfer information is expressed formally in a Request for Service (RFS) which must be validated (i.e., approved as to need). If the proposed requirements cost more than $200,000 per year to lease, or more than $500,000 to buy, the Office of the Secretary of Defense must approve the request. Smaller requests are approved within the military departments. Once validated, a requirement must be certified. Certification involves determining if the method of satisfying a requirement is compatible with existing technology and if funds are available. Once certified, the RFS becomes a Telecommunications Service Request (TSR) which is essentially a purchase order. The TSR is sent to the appropriate DCA office for implementation. Requests for leased communications services and for DCS common-user switched services are sent to the Defense Commercial Communications Office (DECCO) of the DCA. Below we discuss in more detail the Air Force, Army, and Navy (including Marines) organizational structure, approval, and budgeting procedures for purchasing communications.

A. AIR FORCE

1. Air Force Organizational Structure

The Air Force is in the process of changing its system of handling its communications needs. Under the old system, the Director of Command, Control, and Communications, Telecommunications Division, Requirements and Policy Branch (AF/XOKCR) managed TCO (Telecommunications Certification Office) functions throughout the Air Force. There are six TCOs: one in each major command and one for headquarters. The TCOs are:

ADCOM	- TCO for Air Defense Command
AFCS	- TCO for CONUS (less commands with own TCO)
PACAF	- TCO for Pacific Theater
SAC	- TCO for Strategic Air Command
USAFE	- TCO for European Theater
HQ USAF (AF/XOOOL)	- TCO for Air Staff, OJCS, OSD, and other Federal agencies

These TCOs will be maintained on an interim basis until the new system is effective.

Under the new system, HQ AFCS will be the central TCO with collateral TCOs for the Pacific and Europe. In addition to processing all approved and funded requirements for leased communications, in FY79 AFCS will assume the management responsibilities for leased communications which were originally held by Air Staff. The collateral TCOs will be responsible for processing their own intra-theater requirements.

2. Procedure

Requests for service costing less than $10,000 are validated by the requiring Major Command Review Board (C3RB) and forwarded to the appropriate TCO for processing. AFCS, in addition, has the responsibility of reviewing requests to determine "the most economical method of providing requested communication services

and to ensure maximum use of spare capability in existing private line services." (AFM100-22) 10 June 1975, p. 5-4). However, the AFCS does not have the authority to approve or disapprove requirements.

Requests costing more than $10,000 must be validated by the major command and forwarded to the Air Staff for approval. If approved, they are sent to the relevant TCOs for processing.

Starting in FY79, unprogrammed new requirements can be processed only if there is an equivalent cost trade-off identified by the major command.

The following is a more detailed account of the approval process for different categories of communications services.

- Major lease requirements (annual lease cost is greater than $200,000, where total lease costs are costs of first year including installation charge): For all military departments, major leased requirements or "above threshold requirements" must be approved at the Office of the Secretary of Defense. An activity submits a request through command channels to HQ USAF/PRC for validation and processing. The Office of the Secretary of Defense is the approval authority. If the request is for service within a unified command, the unified commander must concur with the requirement. Once approved, the requirement then is sent to the relevant TCO for further processing.
- Minor lease requirements (less than $200,000):
  - Requirements from $100,000 to $200,000--must be approved by HQ USAF/PRC.
  - Requirements below $100,000 are approved at MAJCOM level. This applies only to existing services. New starts costing more than $10,000 must be approved by HQ USAF/PRC.
- Non-DCS requirements (such as tactical facilities) are approved by MAJCOM. Requirements that might be satisfied by DCS facilities are forwarded to DCA.
- JCS requirements are validated and approved by JCS. Unified or specified command requirements are approved by the unified or specified command.

HQ USAF requirements are approved at HQ USAF. If a requirement goes overseas, it must be approved by the appropriate theater commander.

- AUTOVON and AUTODIN requirements are approved through command levels to the MAJCOM. Some requirements must have HQ USAF or JCS approval because of cost or precedence level. AFCS is the TCO for all the common-user requirements.

- Requests for emergency requirements may bypass paperwork. Requests are approved, validated, and forwarded to DCA orally. In some cases, TCOs or the commander of a MAJCOM can place oral orders directly with the commercial common carriers. Emergency requirements are defined as those where immediate processing of service is needed for accomplishing the MAJCOM's "regularly assigned combat mission or an assigned emergency military task." (AFM100-22, pp. 5-10).

All dedicated circuits are reviewed annually by the major commands and justified by the TCO. The procedure is being revised so that the dedicated circuits must be justified to HQ AFCS. Also, the reporting and budgeting cycle will be made to coincide so dedicated services not justified can be dropped. AFCS is responsible for conducting a semi-annual review of AUTOVON access line configuration.

For requirements approved at the major command level, the MAJCOM has the responsibility to:

- "Ensure that funds are available for requirements that it has approved;
- Recommend restoration priority and rationale supporting recommendation;
- Ensure compatibility of requirements;
- Conduct annual reviews."

Also, "Commanders at all levels must ensure that each requirement is firm before its submission to the TCO. Requirements that are continually modified indicate inadequate planning and result in wasted resources." (AFM100-22, 10 June 1975, pp. 5-10).

The TCOs have the responsibility to determine if services requested are technically feasible and if supporting funds are available. HQ AFCS, in addition, has the responsibility of "Reviewing all proposed service requests to ensure maximum use of space capability in existing private-line services and determining the most economical method of providing requested communication services." (AIM100-22, para. 5-7).

3. Fiscal Responsibility

Under the old system, the MAJCOM's and separate operating agencies of the Air Force sent budget requests to AFCS. AFCS reviewed requirements and forwarded a consolidated request to HQ USAF. The Air Staff (through the Operating and Budget Review Committee) determined what funds could be provided to the AFCS for communications services. AFCS allocated the money among the MAJCOMs.

Under the new system, AFCS will receive the funds for common-user systems. Like the old system, MAJCOMs will submit requests for common-user services to AFCS and AFCS will be the level of fiscal responsibility. However, unlike the old system, money for other long-haul leased communications will be included in O&M budgets at the MAJCOM level. AFCS will continue to actually write the checks for dedicated circuits and they will make suggestions to the MAJCOMs concerning less expensive alternatives.

B. ARMY

1. Army Organizational Structure

The U.S. Army Communications Command (USACC) is a major Army command with the responsibility to provide all Army communications above Corps level not assigned elsewhere.

The U.S. Army Commercial Communications Office (USARCCO), located at Fort Huachuca, Arizona, is a subordinate command of

USACC and is the Telecommunications Certification Office (TCO) for the Army. As the Army's TCO, USARCCO certifies requests for long-haul communications (RFS) by issuing a Telecommunications Service Request (TSR) to DCA. USARCCO also has the responsibility to maintain the Leased Communications Management Information System (LCMIS), the primary Army data bank. USARCCO serves as the Army's fiscal manager for long-haul leased communications and advises USACC on matters pertaining to leased communications. In addition, USARCCO performs a management evaluation of all RFS, approves AUTOVON and FTS requests, and conducts the Army's annual review and revalidation of all non-common-user long-haul leased services.

Like USARCCO, the Signal Corps are also subordinate commands of USACC. Communications Electronics Offices (C-E) are elements of the Signal Corps and are referred to as USACC's Intermediate Commands. There are forty-one C-E offices, one for every ten to twelve posts. They are manned by USACC personnel. The C-E (USACC) commander is "dual-hatted" because he also serves as principle C-E staff for the local operational or MACOM commander.

2. Procedure

A potential user of communications services first states his requirements to the supporting C-E office. The staff of the C-E Office reviews the requirement. If an RFS is required, it is drawn up and submitted to the MACOM for validation. A user usually states also the means by which his requirement is to be satisfied. In order to help determine the specific means of satisfying a requirement, a user works with the C-E Office or USARCCO from the start. The user obtains additional help in the form of a field manual written by USARCCO.

Once the RFS is validated by the MACOM, it is sent to the USACC Intermediate Command which readies it for submission to USARCCO. This involves verifying or performing an economic

analysis of the RFS and checking that all necessary information is available. In the case where the user is part of a different MACOM than his supporting C-E Office, the RFS is sent to the user who readies it for submission to USARCCO through his MACOM. If there is no USACC Intermediate Command for an organization in CONUS, the validated RFS is sent directly to USARCCO.

USARCCO performs a management evaluation (ME) and certifies the requirement by issuing a TSR. The management evaluation process at USARCCO has saved millions of dollars so far. About 70 percent of RFS are challenged on some basis, although most often they are just procedural. USARCCO can (and does) suggest alternative means of satisfying a requirement and can reject a specific method if it is deemed uneconomical. If a specific means of satisfying a requirement is rejected by USARCCO because it is not economical, the decision can be appealed to USACC HQ/HQDA, but it is rarely done. Often USACC can persuade a user into an alternative by having the user try it for a month.

Once the management evaluation is performed, USARCCO issues a TSR and submits it to DECCO for leased services, or to DCAOC or DCA-Pacific for DCS service.

For FTS service, the user first states requirements to the supporting C-E Office. Then the request is forwarded to the area C-E Office, the MACOM, and finally to USARCCO. USARCCO then sends all qualified FTS requirements to GSA or DECCO for implementation.

For long-haul requirements in Europe, the user submits an RFS to the 5th Signal Command in Europe (the validating office) and to USARCCO (the TCO) simultaneously. The validating office evaluates the impact on Europe and USARCCO makes a management evaluation of the RFS. The two offices resolve differences by phone and USARCCO submits the TSR to DCA-Europe.

For long-haul Pacific requirements, a user submits an RFS to the proper USACC support element for economic analysis,

validation and forwarding to USARCCO. USARCCO obtains approval from CINCPAC or JCS as needed before submitting a TSR to DCA.

For BASECOM (short-haul) leased communications services, the user goes to USACC O&M commands. USARCCO is not involved in the requirements approval process for this type of communications.

Review and revalidation of communications is performed annually. USARCCO provides information concerning review and revalidation schedules and procedures.

3. Fiscal Responsibility

USARCCO consolidates and forwards the MACOMs budget requests for long-haul leased communications. After the budgeting process, USARCCO receives a budget allocation with cutbacks. While priorities are fairly well established, USARCCO has a little flexibility in allocating cutbacks.

USACC and USARCCO are the lowest levels of fiscal responsibility for the Army. While lower levels are constrained by the fact that they do not automatically obtain all they requested, they are not the ones who actually pay the bills.

The budget dollars go to USACC and USARCCO for allocation to highest priority requirements. The Army feels that if the communications dollars were allocated to the MACOMs, one MACOM may have enough funds for a project while another MACOM may have no funds for a higher priority project. Also each MACOM would have to keep its own safety margins to prevent exceeding their budget for special cases. USARCCO controls requirements through their ability to set priorities.

The Army uses several other methods to control communications expenditures. If requirements money is not in the program, the user may be forced to find his own funding by reprogramming other funds. Sometimes MACOMs are told they can have a service

if they give up another one. As stated earlier, USARCCO may try to persuade a user to try a different means on a temporary basis. Sometimes USARCCO rejects a means as being uneconomical.

USARCCO gets involved in several areas other than leased communications services. USARCCO helps to cost out alternatives for new special purpose networks. In addition, USARCCO helps USACC HQ in the design and procurement of new government-owned facilities.

C. NAVY

1. Navy Organizational Structure

CNO is the validation authority for the Navy. The Commander of the Marine Corps is the validation authority for the Marine Corps. Otherwise, the Marine Corps approval process follows the same procedures as the Navy. Two second echelon commands are responsible for the review and management of communications requirements. The Chief, Naval Material, Navy Facilities Engineering Command, is responsible for administrative telephone service. The Commander, Naval Telecommunications Command (COMNAVTELCOM) manages DCS for the Navy and the Naval Telecommunications System (NTS) and is the Navy Telecommunications Certification Office.

Within COMNAVTELCOM are two divisions. Validation and review of requirements are performed in one division; the other division certifies requirements and prepares TSRs.

2. Procedure

Users submit requirements through their commands. They are encouraged to include their recommendations concerning the method of satisfying the requirement. If the request involves the transfer of data, the request must be approved by Commander, Navy Data Automation Command (COMNAVDAC). The requirements then go to

COMNAVTELCOM for review and consolidation before being forwarded to CNO for validation and programming.

CNO is the validating authority for all communications services (except "above threshold" leases and equipment). Before requirements are forwarded to CNO for validation, COMNAVTELCOM reviews the available alternatives to determine the best method of fulfilling the requirement and "resource implications."

Since COMNAVTELCOM analyzes the "resource implications" and makes recommendations to CNO, it has some authority to choose which requirements are implemented and exactly how the requirements are satisfied.

The RFS' with COMNAVTELCOM's recommendations are sent to CNO for validation. Validated RFS' are then returned to the certification branch of COMNAVTELCOM.

The validated and funded requirements are changed into Telecommunications Service Requests and forwarded to DCA. COMNAVTELCOM, as Navy TCO, also issues TSRs for long distance telephone and telephone data services leased through DECCO for Naval Facilities Engineering Command.

If the user's request for service is not in cycle with the PPBS, the validation procedure is basically the same, but the requesting activity must provide funds until approval of the program and budget. Since requirements must be submitted about two years in advance in order to be in cycle with the PPBS, many requests are out of cycle.

Review and revalidation of dedicated communications occurred in conjunction with the JCS Network Review Panel. With the demise of this panel, Navy has initiated a biennial review of all dedicated service.

3. Fiscal Responsibility

Most requests for service are validated by COMNAVTELCOM and subsequently by CNO. If out of cycle with the PPBS, the requesting activity must find its own funds.

However, COMNAVTELCOM does not fund all requests or automatically accept the user's choice of method. The requirements branch suggests alternative methods of satisfying the requirement. The certification branch may determine that funds are not available. Since COMNAVTELCOM determines if funds are available, COMNAVTELCOM is the lowest level of fiscal responsibility in the Navy.

D. SUMMARY AND CONCLUSION

In all the military departments, the user is urged to specify the means of satisfying his communications requirement. If the request is not in cycle with the PPBS, the user must provide his own funds for the project. If in cycle with the PPBS, the user still may not be able to satisfy his need as he wishes. Since actual budgets are typically smaller than the amounts requested, there is an excess demand for communications funds. The budgeted dollars are given to the communications commands to allocate. Thus, the communications commands, in their attempts to stretch the limited communications dollars, are perhaps the lowest level of price-responsiveness in the military departments.[1] While users may be cost conscious, especially for non-budgeted items, the communications commands face an actual and binding budget constraint. As budgets are tightened, the communications commands transfer this pressure down to the lower levels by turning down more requests and by searching for cheaper methods of satisfying a user's requirement. This sometimes involves

[1] In the Air Force's new program, this level will be lowered to the MAJCOM level for communications services excluding the switched systems. Funds for AUTOVON and AUTODIN will still be allocated by the AFCS.

persuading the user to accept different characteristics of services (or perceived characteristics) in order to decrease costs.

The role of the communications command (or MAJCOM in the Air Force's new program) is an important one. It is the lowest level where the budget constraint is binding for communication services. Since the commands allocate budgeted funds and pay the bills, whenever budgeted funds are less than requested funds the communications commands cannot fund all requests. In fact, as communications funds have become tighter, there has been pressure for reorganization within the military departments in order to control communications costs. The communications commands have become more involved in working with the user to determine how his requirement can be satisfied at a lower cost.

APPENDIX D

CHARACTERISTICS OF DCS SERVICES

CHARACTERISTICS OF DCS SERVICES

The Defense Communications System provides transmission service for long-haul defense communications. Transmission service is provided on a number of distinct DCS systems, by a number of different technologies, and through three principal methods:

- Under message-switching, the user's information is stored at various network switches and forwarded toward the intended destination as appropriate circuits become available. DCS message-switching networks include AUTODIN, ARPANET, WIN and (soon) AUTODIN II. The last three of these networks employ an extremely fast switching technique called packet-switching, which permits end-to-end transmission almost as though a direct circuit were connected between users.
- Under circuit-switching, network circuits are temporarily switched to form an end-to-end circuit directly linking origin and destination users. Users then control the transfer of information along that circuit. DCS circuit-switching networks include AUTOVON, AUTOSEVOCOM, and ATSS.
- With dedicated circuits, origin and destination users are permanently connected by end-to-end circuits. Within the DCS, dedicated circuits are provided by commercial lease, DCS multiplex systems, DSCS, and by other government-owned facilities. These methods of providing transmission service are summarized in Table D-1, together with the corresponding DCS systems.

The following discussion describes the transmission services provided by the various DCS systems. These services are described in the context of the characteristics of user needs discussed in Appendix B. This format facilitates comparison of the services of various systems from the viewpoint of

satisfying user needs. Also included is an indication of whether subscriber charges for each system vary with type of service chosen. Subscriber charges are discussed in more detail in Appendix F. Finally, certain commercial telephone and telegraph systems are included for purpose of comparison. While these systems are used for defense communications, they are not considered to be DCS systems.

Table D-1. METHODS OF PROVIDING DCS TRANSMISSION SERVICE

<u>Message Switching</u>[1]

- AUTODIN (Automatic Digital Network)
- ARPANET (Advanced Research Projects Agency Network)[2]
- WIN (WWMCCS Inter-computer Network)[2]
- AUTODIN II[2]

<u>Circuit Switching</u>[3]

- AUTOVON (Automatic Voice Network)
- AUTOSEVOCOM (Automatic Secure Voice Network)
- ATSS (Alaska Telephone Switching System)

<u>Dedicated Circuits</u>[4]

- Commercial Lease
- Multiplex Systems
  - VFCT Systems (Voice Frequency Carrier Teletype)
  - Channel-Packing Systems
  - 1.544 mbps Systems
  - WAWS (Washington Area Wideband System)
- DSCS (Defense Satellite Communications System)
- Other Government-owned Facilities

[1]Information is forwarded to selected destination.

[2]These are packet-switching networks on which information is forwarded to its destination as rapidly as would be possible with a direct circuit.

[3]Circuit is temporarily connected between origin and selected destination.

[4]Circuit is permanently connected between fixed points.

A. TRANSMISSION CAPABILITY

1. AUTODIN

This network provides a message-switching service for alphanumeric messages as well as for data transfer. A special version of message-switching called Query/Response service is offered to facilitate remote terminal access to computers. AUTODIN access lines (between subscriber terminals and AUTODIN switches) may operate at several different line-speeds, ranging from 75 up to 4800 bps (i.e., bits per second). As discussed under Delivery Time below, the effective end-to-end line-speed is usually lower than that of the access lines, since the information is stored for some time at the AUTODIN switches. In addition, acknowledgment procedures to detect transmission error reduce the effective rate of transmission below the nominal line-speed. The subscriber has several options in this regard.

Subscriber charges for AUTODIN increase with the line-speed of access lines, in accordance with the following categories:

- low (75 to 300 bps)
- medium (600, 1200 bps)
- high (2400, 4800 bps).

2. ARPANET, WIN

These are special-purpose networks available to limited groups of subscribers. They employ packet-switching (an advanced form of message-switching) techniques, and are designed to provide transmission line-speeds suitable for various computer applications. Nominal line-speeds for access lines range from under 300 bps to 56,000 bps. Effective line-speeds are considerably lower, due to control procedures and switching delays. Subscriber charges are at the discretion of switch owners. Lease charges for access lines increase with nominal line-speed capability.

3. <u>AUTODIN II</u>

This packet-switching network will be operational in December 1979 and will eventually replace ARPANET, WIN, and a number of dedicated networks. In addition to the same line-speed options as are available on AUTODIN, AUTODIN II subscribers will be able to connect access lines with nominal capabilities of 9600, 19,200, and 56,000 bps. Effective end-to-end line-speeds will be lower than these nominal levels due to control procedures and switching delays. In addition, the rates at which subscribers transmit data to the network will be closely regulated to prevent congestion on the AUTODIN II backbone. As a result, end-to-end line-speed will be degraded during busy periods for low-priority users. Subscriber charges will increase with the line-speed capability of access lines.

4. <u>AUTOVON</u>

This network provides a common-user circuit-switching service. The circuits have bandwidth and conditioning suitable for voice (telephone) transmission. The circuits can also be used for data transmission, if modems are used at each end to convert the digital data signal to a form suitable for transmission on an analog voice circuit. AUTOVON circuits are conditioned so that data can be transmitted at line-speeds up to 2400 bps. Error rates are usually unacceptable to data users when higher line-speeds are used. There are a few data-grade circuits overseas, conditioned to permit transmission up to 4800 bps, or even up to 9600 bps for single-segment circuits. Subscriber charges for data-grade circuits are double the charges for voice-grade circuits.

5. <u>AUTOSEVOCOM</u>

This is a circuit-switching network designed to provide for encrypted voice transmission. This permits voice communication

of classified information. Due to the encryption process, the signal to be transmitted is a digital signal. The quality of end-to-end voice reception improves when equipment requiring higher transmission line-speed is used. But if the circuits used are not suitably conditioned for the line-speed transmitted, then the quality of voice reception again deteriorates.

Subscribers may have encryption equipment and access lines appropriate for transmission at 2400, 9600, or 50,000 bps. A 50,000 bps subscriber transmitting via one of the small number of 50,000 bps AUTOSEVOCOM circuits receives relatively good voice quality. But most calls are routed via AUTOVON circuits, even when they originate at 50,000 bps. As a result, voice reception on AUTOSEVOCOM is frequently quite poor.

Subscriber charges to AUTOSEVOCOM subscribers are at the discretion of the owners of the respective AUTOSEVOCOM switches.

6. ATSS

The Alaska Telephone Switching System provides a circuit-switching service among subscribers within Alaska, and also provides inter-connection with AUTOVON. The ATSS circuits are suitable for voice transmission, or for data transmission at up to 2400 bps.

7. Dedicated Circuits

These circuits provide private-line transmission services for both voice and data. The line-speed capabilities available range from 50 bps up to millions of bps. This entire range can be obtained on commercially leased dedicated circuits, with lease charges increasing with transmission capability.

Dedicated circuits are also provided by a variety of DCS multiplex systems. A multiplex system is one in which equipment is used to subdivide a transmission channel into a number of channels with smaller transmission capabilities than the

original channel. VFCT (Voice Frequency Carrier Teletype) systems provide teletype channels with line-speed capabilities of 75 bps. Channel-packing systems provide channels with line-speed capabilities ranging from 75 up to 9600 bps. The 1.544 mbps (i.e., million bps) systems provide voice-grade channels which can be used to transmit data at line-speeds up to 9600 bps. Finally, the Washington Area Wideband System (WAWS) provides channels with line-speeds ranging from 1.544 mbps up to 36.818 mbps. Subscriber charges are determined separately for each of the multiplex systems. For any given system, subscriber charges increase with line-speed capability.

Dedicated circuits with a wide range of transmission capabilities are also available on the Defense Satellite Communications System (DSCS) and other government-owned facilities. There are no subscriber charges for the use of government-owned facilities.

8. Commercial Telephone

Commercial telephone companies provide a circuit-switching service. The circuits are voice-grade, and can be used to transmit data at line-speeds up to 2400 bps. Higher line-speeds are possible, but require expensive conditioning equipment in order to control transmission error.

9. Commercial Telegraph

Western Union's Telex and TWX services provide both message-switching and circuit-switching services. The circuits have line-speed capabilities of from 50 to 150 bps. Subscriber charges do not vary with line-speed.

Transmission capabilities for the various DCS systems are summarized in Table D-2.

Table D-2. TRANSMISSION CAPABILITIES OF DCS SYSTEMS

SYSTEM	TRANSMISSION CAPABILITY
AUTODIN (Message Switching)	Access lines transmit data at 75, 150, 300, 600, 1200, 2400, or 4800 bps. Backbone trunks transmit at 1200, 2400, or 4800 bps.
ARPANET, WIN (Packet Switching)	Access lines transmit data at up to 56,000 bps. Backbone trunks transmit at 50,000 bps.
AUTODIN II (Packet Switching)	Access lines transmit data at 110, 150, 300, 600, 1200, 2400, 4800, 9600, 19,200, 56,000 bps. Backbone trunks transmit at 9600, 19,200, 56,000, 230,000 bps.
AUTOVON (Circuit Switching)	Circuits for voice, or for data at up to 2400 bps. Few circuits for data at up to 9600 bps.
AUTOSEVOCOM (Circuit Switching)	Access lines and backbone trunks transmit digitized voice at 2400, 9600, or 50,000 bps.
ATSS (Circuit Switching)	Circuits for voice, or for data at up to 2400 bps.
Dedicated Circuits (Permanent Circuit)	Commercial lease for voice, or data at from 50 to millions of bps. Multiplex Systems: VFCT for teletype at 75 bps. Channel-Packing for data at 75, 150, 300, 600, 1200, 2400, 4800, 7200, or 9600 bps. 1.544 mbps for voice, or for data at up to 9600 bps. WAWS for data at from 1.544 to 36.818 mbps. DSCS and other government-owned for voice, or for data at from 50 to millions of bps.
Commercial Telephone (non-DCS Circuit Switching)	Circuits for voice, or for data at up to 2400 bps.
Commercial Telegraph (non-DCS, Message Switching or Circuit Switching)	Message transmission at from 50 to 150 bps.

B. DELIVERY TIME

1. AUTODIN

As noted above, the elapsed time necessary to transmit a message on a circuit depends on the length of the message, the distance to the destination, and the transmission line-speed. For a message-switching service such as AUTODIN, the message is transmitted not on a single circuit, but over a network of switches and trunks. The effective line-speed may be reduced on such a network for at least three reasons:

- network signaling and error-control procedures reduce the proportion of transmission which is useful information;
- it takes time to switch messages from trunk to trunk;
- during busy periods, messages must be stored at switches until appropriate outgoing trunks are available.

These effects are partially offset in those cases where access lines operate at lower line-speeds than network trunks. For these reasons, the line-speeds of access lines and network trunks are not accurate guides to the elapsed time required to transmit messages, or streams of data messages.

The Joint Chiefs of Staff (JCS) have established objectives for the maximum elapsed time for transmission of short messages. These "speed-of-service" objectives measure the elapsed time from the beginning of transmission to the origin AUTODIN switch until the end of transmission from the destination switch. Speed-of-service objectives are established by precedence level as follows:

Precedence	Speed of Service
Flash	10 minutes
Immediate	30-60 minutes
Priority	1-3 hours
Routine	3 hours--start of next business day.

Precedence is available to all subscribers, but may be invoked only when the substance of a message meets certain command-and-control criteria. While these objectives are evidently met, they clearly permit storage delays to dominate in the determination of delivery time.

A special AUTODIN service, Query/Response, has been introduced to provide better service to subscribers accessing remote computers. Query/Response subscribers have the same line-speed options for access lines as ordinary subscribers, and subscriber charges increase with the line-speed chosen. But delivery time is reduced for Query/Response subscribers by certain provisions for special handling. For one thing, Query/Response messages are usually permitted to claim "immediate" precedence, and are stored at the head of their precedence queues at AUTODIN switches. Further, Query/Response headers (i.e., procedural information for each message) are abbreviated relative to ordinary headers. Despite these improvements, even Query/Response does not permit end-to-end transmission line-speed equivalent to the line-speed of the access line.

Special provisions have been made for certain high-priority subscribers to dramatically reduce delivery time. Their information is permitted to bypass the usual switching and queuing procedures.

2. ARPANET, WIN

There is no real storage of messages at switches for packet-switching networks. But effective line-speed is still lower on an end-to-end basis than the nominal line-speed of access lines and network trunks would suggest. Delays are caused by network signaling and control procedures, and by the switching process itself.

On ARPANET, for example, network procedures limit the delivery of information to the network to 19,200 bps. A typical

message (containing up to 8063 bits of useful information) is transmitted from origin to destination subscriber in less than 250 milliseconds. This is adequate to permit end-to-end transmission at the 19,200 bps rate of input. The actual line-speed over the network varies with the amount of congestion and the particular locations involved.

3. AUTODIN II

This packet-switching network will produce network delays similar to those of ARPANET and WIN. The precedence system used for AUTODIN messages will apply to messages sent on AUTODIN II. No formal objectives have been established for effective end-to-end line-speed.

4. AUTOVON, AUTOSEVOCOM, ATSS, Dedicated Circuits

For circuit-switching networks and dedicated circuits, delivery time is determined by distance, amount of information, and line-speed, once the circuit is established.

5. Commercial Telegraph

Message-switching subscribers may choose same-day or overnight delivery, paying less for the latter.

C. AVAILABILITY OF SERVICE

1. AUTODIN

Each subscriber has a direct circuit permanently connected to an AUTODIN switch. Thus the message-switching service is virtually always available, albeit the information may be stored at the switch if the network is congested. Message preparation can delay access to the network, due to AUTODIN format procedures. Some concessions are made in this regard on the Query/Response service, such as permitting abbreviated headers. Also,

availability may be a problem for individual users who share an AUTODIN access line.

2. ARPANET, WIN, AUTODIN II

Packet switches have very little capacity to store information. Accordingly, subscribers are permitted to deliver messages to the network only when the network is able to deliver them to their intended destinations. In addition to reducing effective line-speed, this may force users to wait to use the network during periods of congestion. Formal objectives for maximum waiting times have not been established.

3. AUTOVON

For AUTOVON, availability refers to the difficulty of obtaining an end-to-end circuit. It is measured by the grade of service, which is the probability that a circuit cannot be connected. End-to-end grade of service depends on the grades of service for:

- outward access lines from caller to AUTOVON backbone (i.e., switches and network trunks);
- the AUTOVON backbone itself;
- inward access lines from AUTOVON backbone to call recipient.

The effective grade of service for individual call attempts varies with the precedence level of the calls. Higher precedence attempts result in pre-emption of circuits being used for lower precedence calls, when necessary to complete the higher precedence calls. The network is sized so that this procedure results in a grade of service for top (i.e., flash) precedence calls of virtually P00 worldwide. The average grade of service for all calls is much worse, and varies from area to area. For the first six months of 1978, the average grade of service for the AUTOVON backbone was:

Area	Grade of Service
Intra-CONUS	P14
Intra-Europe	P04
Intra-Pacific	P26
CONUS to Western Pacific	P19
CONUS to Hawaii	P16
CONUS to Europe	P43
CONUS to Caribbean	P14

The JCS standard for inward grade of service (between backbone and call recipient) is P05. In practice, the inward grade of service is much worse than this. The outward grade of service (between call originator and backbone) is to be determined based on mission, but is typically much worse than P05. Thus, the end-to-end grade of service can be quite bad. For example, the average percentage of call attempts not completed for a sample taken in July 1978 was:

Area	% Incomplete
Western Hemisphere	40.0%
Overseas	31.7%
Pacific	30.0%
Europe	32.0%

These statistics do not include calls blocked before reaching the AUTOVON backbone.

Subscriber charges increase with the maximum precedence capability of each access line. That maximum is determined by the JCS, based heavily on command-and-control requirements. Subscribers also can obtain access lines wired directly between user and AUTOVON backbone. Such "4-wire" phones permit the user to avoid outward congestion on access lines connected between the local PBX and the AUTOVON backbone. Four-wire access lines cost no more but are reserved (in principle) for subscribers with at least immediate level precedence authorization. Another way that subscribers can affect availability is by altering their mix of access lines (at PBXs) with

capabilities to send only, to receive only, or to send and to receive. Subscriber charges are twice as high for send-only as for send-and-receive lines. There are no subscriber charges for receive-only lines.

AUTOVON provides special features affecting availability, such as off-hook service, truncated dialing, and dual-homing.

4. AUTOSEVOCOM

Availability for AUTOSEVOCOM is also measured by the grade of service. Because most AUTOSEVOCOM calls are routed over AUTOVON trunks, the grade of service for AUTOSECOVOM is largely determined by that for the AUTOVON backbone. Grade of service for the few AUTOSEVOCOM wideband (i.e., 50,000 bps) trunks is controlled by limiting which subscribers may access those trunks. This determination is made locally by the military departments. Charges to individual AUTOSEVOCOM subscribers are at the discretion of the owners of AUTOSEVOCOM switches.

5. ATSS

Availability for the Alaska system is also measured by the grade of service. Because the Alaskan switches embody obsolete technology, there is no pre-emption capability for calls within ATSS, or from ATSS to AUTOVON (in CONUS). Thus ATSS does not provide P00 service for flash calls.

6. Dedicated Circuits

Dedicated circuits are permanently connected and hence always available to their subscribers. Where there are a number of users of a dedicated circuit, availability could be measured by grade of service or average waiting time. In any event, availability is under the control of the subscriber, who can control the number of dedicated circuits obtained. To

the extent that subscriber or lease charges exist, those charges increase with the number of dedicated circuits.

Log-on and identification procedures are usually less cumbersome than on common-user networks. Special features such as off-hook service or truncated dialing are readily available. Technical reliability does vary somewhat among the alternative DCS systems which provide dedicated circuits. By themselves, dedicated circuits may be less survivable than the common-user networks, due to the redundancy built into the latter.

7. Commercial Telephone

Availability is measured by the grade of service, which is approximately P01 for local service, and P03 for long-distance service. Pre-emption is not available, so that service even to high precedence users can deteriorate during periods of unusual congestion (e.g., hostile attack).

8. Commercial Telegraph

Availability would be measured by grade of service. During periods of unusual congestion, circuits can be pre-empted away from Telex and TWX to meet the needs for public telegram service.

D. COMMUNITY OF INTEREST

1. AUTODIN

This network provides service to CONUS, Europe, and the Pacific. There are approximately 1200 subscribers, and over 5000 addressable destinations. Regular subscribers automatically obtain access to the entire network. Their subscriber charge does not depend on the area of the network to which they actually send their messages. Subscribers may be individual users, or may be communications centers through which a number of users share AUTODIN access lines.

Under the Query/Response service, subscribers may communicate with up to six particular destinations (of their choosing). Subscriber charges increase with the number of destinations selected, and with whether they are located in:

- CONUS, Europe, or the Pacific;
- CONUS and Europe or CONUS and the Pacific;
- CONUS, Europe, and the Pacific.

2. ARPANET

Subscribers have access to all ARPANET switches in CONUS, London, and Norway. Access to particular computer facilities or other subscribers must be pre-authorized. The ARPANET community is largely specialized to research-oriented subscribers. Subscriber charges are flat monthly fees and do not reflect the areas actually called.

3. WIN

This is a command-and-control network approximately co-located with command authorities down to the major command level. Subscribers have access to the entire WIN backbone.

4. AUTODIN II

Subscribers will have access to the entire AUTODIN II backbone. It will initially be limited to CONUS, but will eventually be extended to Europe and the Pacific. Subscriber charges will be flat monthly fees, and will not reflect the locations actually called.

5. AUTOVON

This network provides service in CONUS, Europe, the Pacific, and the Caribbean. There are approximately 17,000 subscribers. They may choose among several options with regard to calling area:

- Global;
- CONUS-Europe, CONUS-Pacific, CONUS-Caribbean;
- CONUS, Europe, or the Pacific;
- Local Service in Europe or the Pacific.

Subscriber charges tend to decrease in the order in which these options are listed.

6. AUTOSEVOCOM

There are over 1500 AUTOSEVOCOM subscribers. Calling area options are the same as those available on AUTOVON, but the choice is made by the owner of each AUTOSEVOCOM switch. Charges to individual subscribers are at the discretion of the switch owner also.

7. ATSS

There are approximately 470 ATSS subscribers. Their subscriber charges provide access to the Alaskan network, and to the inter-connection with AUTOVON in CONUS.

8. Dedicated Circuits

Dedicated circuits are available worldwide, but the systems which provide these circuits vary from area to area. For example, commercial leases are only available in the United States and certain other advanced industrial countries. Multiplex systems are available over a limited number of routes.

Subscribers control the points inter-connected, and hence can tailor dedicated service to their exact communities of interest. To the extent that subscriber or lease charges exist, the subscriber's cost increases with the extent of the community.

Subscriber costs mount rapidly as dedicated networks expand. If all users are directly inter-connected, the number of lines required increases rapidly with the number of users. If there

are n users, there must be $\frac{n(n-1)}{2}$ lines, and the addition of one user when n are already connected requires n new lines. Costs do not mount as rapidly if additional users are connected serially on multi-point dedicated circuits, or if switches are added to the dedicated network.

9. Commercial Telephone

Subscribers may choose between toll service with potential access to the entire commercial network, and WATS service with potential access only to certain pre-arranged distance bands. Toll charges vary with location and distance called, while WATS charges vary with the distance chosen.

10. Commercial Telegraph

Subscribers have access to the Telex and TWX networks throughout the U.S., with connections to networks in other countries. Subscribers pay a monthly connectivity charge, plus a usage charge which varies with the distance over which the messages are actually sent.

E. TIMING AND AMOUNT OF USE

1. DCS

Within the DCS, subscribers usually have access to the respective communications systems, 24 hours per day, seven days per week.

Services are not offered for smaller amounts of time, or for particular times of the day only. Accordingly, there are no options to pay subscriber charges based on less than full-time use, including the amount or the time-of-day use. In principle, DCS dedicated circuits can be obtained commercially on a part-time basis, with charges varying with the time of day and with the amount of time reserved. But apparently such leases are rare.

2. Commercial Telephones

The bill for toll telephone service varies with the number of calls, their duration, and the time of the day and week at which the calls are made. WATS subscribers are offered a choice between Measured (10 hours per month) and Full Business Day (240 hours per month) service, with charges varying with the service chosen, and with any additional hours used. WATS charges do not vary with the time at which calls are actually placed.

3. Commercial Telegraph

Telex and TWX services are available to subscribers on a full-time basis only, but charges are based on the amount of time the services are actually used.

APPENDIX E

ECONOMIES OF CENTRALIZATION: DISCUSSION AND EXAMPLES

ECONOMIES OF CENTRALIZATION: DISCUSSION AND EXAMPLES

This study has referred frequently to the possibility of reducing government costs by satisfying more DCS requirements on centralized, common-user systems. While centralization is not appropriate in all circumstances, there are definite reasons to anticipate cost savings in many important cases. This appendix provides further information on the sources of such potential savings:

- Section A provides a background discussion on the types of centralization economies available in many different industries.
- Section B presents an example directly relevant to the DCS, illustrating the advantages of circuit-sharing.

A. BACKGROUND DISCUSSION OF ECONOMIES OF CENTRALIZATION

1. Introduction

The term "economies of scale" is commonly used to describe a variety of cost-quantity relationships where unit costs fall as output increases. Unit or average costs may vary with changes in output, however, for a variety of reasons. These include changes in the utilization of indivisible resources, increasing or decreasing returns to scale and changing factor prices. In the case of communications services, the concept is especially difficult to pin down because product quality (e.g., the grade of service) is a variable and, in addition, most production activities involve multi-product outputs.

For a firm producing only one good of fixed quality, economies of scale refers to a situation where long-run average

cost declines as output increases. Aside from decreases in input prices, declining long-run average cost could result either from indivisibilities in certain inputs or from increasing returns to scale in the production function for the product. Strictly speaking, the term economies of scale is applicable only in the long-run where all inputs can be varied by the firm to achieve the cost-minimizing combination of inputs for each level of output. Certain inputs, however, may be inherently indivisible so that very small amounts are simply unavailable and additional units can be acquired only in discrete amounts. In such situations, the unit cost of producing small levels of output is likely to be relatively high and will decline with increases in output. If the indivisible input is not employed at low levels of production, alternative and presumably less desirable inputs must be substituted until ouput reaches a level which warrants the introduction of the indivisible resource. Once the indivisible factor is introduced, costs per unit will continue to fall (at least for a certain range) with increases in output because of the fuller utilization of this semi-fixed factor. Even if the indivisible factor is used from the very beginning, unit cost will still decline as output increases because of the more intensive use made of this factor which is available in greater than optimal amounts at low levels of output. In situations such as these, economies of scale (i.e., falling average cost) could be realized even though the production function of the firm is of the constant (or even decreasing) returns to scale variety.

A more basic reason for the existence of economies of scale which arises directly from the production function of the firm is the presence of increasing returns to scale. Increasing returns to scale refers to a situation where a change of all of the firm's inputs by the same percentage results in an even larger percentage change in the level of output. In such a case, a doubling of all inputs would result in a more than

doubling of output and cost per unit of output would decline. This phenonmenon is believed to be an important characteristic of production and distribution in so-called public utilities such as electricity, water and telephone service.

The obvious implication that has been given to the existence of economies of scale over a broad range (in a world where firms produce only one product) is that one large firm can produce a given quantity of a particular good at a lower cost than can two or more smaller producers. This situation is often described as a natural monopoly where production by one supplier as opposed to two or more smaller ones is justified on technological grounds. This question of what number of firms or suppliers constitutes the least-cost arrangement for providing a particular set of goods or services is of crucial importance in the analysis of the Defense Communications System's approach to providing its various services. It will be shown that the answer to this question is intricately linked to (but not completely determined by) the existence of economies of scale when properly defined for a multi-product firm.

2. Economies of Scale and Products with Multi-Dimensional Characteristics

In the case of a communications system providing services such as those of AUTOVON and AUTODIN, several different (although related) services can be produced by the same organization where each different service has a quality (e.g., grade of service) as well as a quantity dimension. In such an arrangement, obvious problems arise involving the allocation of costs which makes it difficult to apply the standard definition of economies of scale discussed above. It seems that, in this context, the term economies of scale has come to represent a generic concept which refers to a variety of cost-quantity relationships where lower unit costs supposedly result from increasing the centralization of the production or acquisition of various

communications services. The term is used to describe both short-run situations dealing with more efficient utilization of existing relationships as well as the traditional long-run relationships focusing upon the effects of changing the capacity of the system. In addition, it is often not clear if the quality dimension is held constant when comparisons are made among various arrangements.

A basic question involving the analysis of cost-quantity relationships in communications is the way in which the quantity and quality of the services can be measured. Even quantity is a multi-dimensional concept involving such things as access to the system (connectivity) and usage of the system (calls, call minutes, etc.) once access is attained. Increasing output can, and often does, refer in some situations to increasing the number of users (connections) while at other times it refers to increasing the usage of the system by the existing members. Since these changes are not made in isolation, it is difficult to interpret the significance of many assertions about changes in costs.

Obviously, increasing the number of connections to a system will decrease unit cost per subscriber (even with fixed capacity) if the grade of service is allowed to deteriorate. Likewise, increasing the usage of a system (e.g., the number of call units) may reduce the cost per call if users are forced to endure longer waits and more uncompleted calls. These situations should not be described as economies of scale or centralization, however, since the quality of the service is being degraded along with the increase in the output(s) of the system. In such situations, reductions in unit costs may arise solely from the reduced quality of the service or from some combination of lower quality and more efficient production arrangements.

If cost is a function of the number of connections, the amount of usage and the grade of service, then economies or diseconomies of scale should refer to changes in access and/or usage for a constant grade of service. This is still not a completely definitive way of viewing the problem since both access and usage can change in a variety of ways. To narrow the definition down even more, economies of scale might be defined as a reduction in unit cost of the system resulting from an equal percentage increase in both connections and usage with the level of service being held constant (presumably through an increase in the capacity of the system in order to keep the quality of the service from declining).

While such a definition of economies of scale is more precise than the previous usage, it is also very restrictive in that there is no reason to believe that all (or even many) changes would take this form. For example, it would be of interest to know how unit costs change with an increase in usage of the system with the same number of connections and a constant grade of service. This relationship would be important for the analysis of the effect of a decrease in the price of usage (if usage-sensitive pricing exists). Similarly, it might also be of interest to know the behavior of costs when the number of connections are increased while usage and grade of service remain the same. This question might be important in analyzing tne effects of a decrease in the connectivity charge accompanied by an increase in the price per unit of usage.

Still further, there is no reason to suppose that the optimal changes in a system would occur with the grade of service remaining the same. For example, if costs fall with greater usage and/or more connections, an optimal adjustment might very well include an improved level of service as well. Likewise, in some situations it may be completely rational to achieve lower unit costs by increasing the number of users of

a system and allowing the grade of service to deteriorate, but this sort of result should not be labeled economies of scale.

Obviously, defining the dimensions of the term economies of scale does not answer many of the important questions, especially the empirical ones, in this area. It does, however, serve to clarify the ways in which the term might be used in describing various cost/quantity relationships. It would be useful when terms such as economies of scale or centralization are used to specify whether the changes in question are short or long-run (i.e., do they deal with changes in the usages of the existing capacity or changes in the amount of capacity and especially, which of the quantity/quality dimensions of output are changing and which are being held constant).

3. Economies of Centralization and the Multi-Product Supplier

In addition to the problems discussed above in dealing with the multi-dimensional nature of the output of any particular communications service, almost every communications system (and virtually every firm in the private sector) is, in effect, a multi-product firm in that a variety of different products or services are rendered simultaneously by a single producer or supplier to a variety of different customers. For example, the provision of voice communications (e.g., AUTOVON), record communications (e.g., AUTODIN) and computer linkages are examples of communications services that can and often are provided by a single supplier. In addition, major variations of the characteristics of service within one category may usefully be thought of as separate products. For example, point-to-point voice communication through a dedicated line is a different product, although one that may be substitutable for membership in the AUTOVON system. Likewise, different levels of precedence available to different subscribers on the AUTOVON system is another example of different, although related, services being offered by a common supplier.

The problem of defining economies of centralization in situations such as these are considerably more complex than for a single product firm and have only been addressed explicitly by economists in the last few years. These findings are of considerable importance in answering the question of what conditions lead to the superiority of a single producer of a variety of products over several smaller producers of one or more of these same products.

In this multi-product context, economies of centralization can arise from two different factors. First, more efficient (in the sense of lower cost) production for a particular mix of outputs may be achieved by increasing the scale of operations. This effect is an extension of the idea of economies of scale discussed above for a single product supplier. If economies of scale exist, one large supplier can produce a certain combination of goods more cheaply than can two smaller firms, each producing exactly one-half the quantities of the goods produced by the larger firm. Economies or diseconomies of scale, however, do not deal with the question of which products should or should not be produced by a supplier nor with the optimal proportions of the various goods which are produced. Instead, it deals only with the effects upon costs of increasing or decreasing the level of output of all goods produced by a firm by the same percentage.

The question of the most efficient combination of products for a firm to produce is referred to under the heading of economies of scope. In non-technical terms, economies of scope refers to cost savings realized by expanding the range (or varying the proportions) of products produced by a single supplier as opposed to efficiencies realized by increasing the levels of output of all products in fixed proportions. More technically, economies of scope exist if it is more costly to have a fixed amount of two goods produced by two firms, each of which

specialized in producing only one of the two products, than it would be to have the same total quantities of output produced by two other firms, each of which simultaneously produces both products.

Economies of scope could result from a variety of complementary relationships in production such as better utilization of excess capacity created from indivisibilities or the utilization of the by-products of one good to produce another good in situations where such by-products cannot be easily sold through normal market processes. There could also be economies of scope in the marketing and distribution of various products. For example, economies in distribution channels, not in production, seem to be the reason that scientific and technical publishers have a full line of books or periodicals in a particular area. Diseconomies of scope may limit, however, the expansion of such publishers into areas far afield from their basic area.

Together, the presence or absence of scale and scope economies tend to shape the least-cost configuration of production and, to the extent that cost factors influence market structure, they shape the structure of various industries as well. For example, if both economies of scale and scope exist in a certain broad area of production, one large firm producing a broad range of products would be the least-cost arrangement for production. Economies of scale without scope economies would likely lead to a series of single product monopolies while economies of scope without scale would lead to many small firms, each producing many products.

For a discussion of the centralization economies most important in the DCS, see Chapter 2 of this study.

B. CENTRALIZATION AS A MEANS OF UTILIZING EXCESS CAPACITY

A major criticism of the use of decentralized arrangements such as dedicated lines for providing communications services is that they are seldom used to full capacity. Even the most intense users of such services will probably have many periods when the lines are idle. If there is less than one hundred percent utilization of such facilities, the possibility exists for a centralized arrangement such as a network to provide similar, although not necessarily identical, service at a lower cost. The potential cost savings discussed here come from the pooling of resources to make possible the sharing of various facilities. The problem with sharing arrangements such as networks, however, is that they may give rise to congestion when many members attempt to use the service at the same time. This is a cost of centralization which must be weighed against the other savings.

1. An Example of Circuit-Sharing Economies

To illustrate the potential for reducing costs through networks, an example of a very simple sharing arrangement will be examined to illustrate the key features. Assume that there are N potential users of a telephone service (all in the same area) which connects them to some distant point. A completely decentralized arrangement might result in each user establishing a line to the distant point, i.e., a number of separate dedicated circuits. In this case there would be one line per user, and much of the time these lines would be idle since each user does not desire to be in contact with the distant point at all times.

For a given period of time, assume that P represents the probability of use of the facility by a particular user. It will be assumed that the probability of use is the same for all users and that each user's probability is independent of

other persons. (Note: This assumption of the independence of the probabilities among users may not always hold true. For example, during an emergency situation such as a war all users may be affected by this event and wish to use the service immediately. This would obviously put a severe strain on a sharing arrangement, making it necessary to allocate the limited capacity to the most important users.) A sharing arrangement can make possible a reduction in the number of lines to less than the number of users, yet still permit a relatively high level of service. These benefits of sharing are illustrated in Tables E-1 through E-5. The techniques used in deriving these results are explained in Section 2 below.

Table E-1 shows the consequences of a sharing arrangement when each user has a probability of use of the facility of .1 during the given time period. The first column gives the number of users while the next four columns give the number of lines necessary to accomodate the users at each of four different grades of service. For example, if two users share a line, and if each has an independent probability of .1 of using the line during a particular time period, there is only a probability of .01 that both will need the line during the period. If this small probability of congestion is acceptable to the users, the two can virtually halve their costs (as compared with the costs for two separate lines). Reading down the second column, it can be seen that (in general terms) the number of lines necessary to accomodate more users at this grade of service (.01) increases at a slower rate than does the number of users (N). This leads to a discussion of columns 6 through 9 which give the average number of circuits per user necessary to accomodate various numbers of users at various levels of the grade of service. It can be seen here that the lines per user decrease fairly rapidly in the early stages and, with a large number of users, it approaches the probability of use which in this case is .1.

Table E-1. CIRCUIT-SHARING ECONOMIES WHEN PROBABILITY OF USE IS .1

NUMBER OF USERS	NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE N USERS WITH A GRADE OF SERVICE OF:				AVERAGE NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE N USERS WITH A GRADE OF SERVICE OF:				NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE AN ADDITIONAL USER WITH A GRADE OF SERVICE OF:			
(N)	P01	P05	P10	P50	P01	P05	P10	P50	P01	P05	P10	P50
2	1	1	1	1	.50	.50	.50	.50	--	--	--	--
3	2	1	1	1	.67	.33	.33	.33	--	--	--	--
4	2	2	1	1	.50	.50	.25	.25	--	--	--	--
5	2	2	1	1	.40	.40	.20	.20	--	--	--	--
10	3	3	2	1	.27	.21	.17	.10	.21	.18	.16	.10
25	5.5	4.5	3.9	2.5	.22	.18	.16	.10	.17	.15	.14	.10
50	9.4	8.0	7.2	5.0	.19	.16	.14	.10	.15	.14	.13	.10
100	16.5	14.4	13.3	10.0	.17	.15	.14	.10	.13	.13	.12	.10
500	65.1	60.5	58.1	50.0	.13	.12	.12	.10	.12	.11	.11	.10
1,000	121.6	115.1	111.6	100.0	.12	.12	.11	.10	.11	.11	.11	.10
2,000	230.8	221.6	216.7	200.0	.12	.11	.11	.10	.11	.11	.10+	.10
10,000	1,069.4	1,048.9	1,037.9	1,000.0	.11	.10+	.10+	.10	.10+	.10+	.10+	.10

Columns 10 through 13 indicate the effect of adding an additional user to the system in terms of the number of additional lines required to keep the grade of service the same. Again, as the number of users increase, the marginal cost of an additional user declines rapidly at first and eventually approaches the probability of use.

Summarizing Table E-1, it can be seen in general terms that increasing the number of users of a system by a given percentage can be accomplished by a smaller percentage increase in the number of circuits while still holding the probability of congestion constant. Likewise, for any level of the grade of service, increasing the number of users reduces the number of circuits necessary per user. The cost of a marginal user in terms of additional facilities also declines as the number of users increase. Obviously, increasing the grade of service for any given number of users will increase the number of circuits necessary, the average number of circuits per user and the extra circuits required for a marginal user.

Tables E-2 through E-5 present similar results based on different assumptions regarding the value of the probability that an individual user will independently need a circuit during the time period in question. The values selected for this probability of use include .25, .5, .75 and .9, respectively. As might be expected, the gains from a sharing arrangement are reduced as the probability of use increases. This is as expected since the increased probability of use reduces the excess capacity which is utilized in the sharing arrangement. For example, comparing Tables E-1 and E-5, it can be seen that 50 users with a probability of use of .1 could combine and use 9.4 circuits and achieve a grade of service of P01. This would be a reduction of 40.6 circuits as compared to the separate provision of the service. (The grade of service would be increased from P00 to P01.) However, if the probability of use is .9 as in

Table E-2. CIRCUIT-SHARING ECONOMIES WHEN PROBABILITY OF USE IS .25

NUMBER OF USERS	NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE N USERS WITH A GRADE OF SERVICE OF:				AVERAGE NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE N USERS WITH A GRADE OF SERVICE OF:				NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE AN ADDITIONAL USER WITH A GRADE OF SERVICE OF:			
(N)	P01	P05	P10	P50	P01	P05	P10	P50	P01	P05	P10	P50
2	2	2	1	1	1.00	1.00	.50	.50	--	--	--	--
3	3	2	2	1	1.00	.67	.67	.33	--	--	--	--
4	3	2	2	1	.75	.50	.50	.25	--	--	--	--
5	4	3	2	1	.80	.60	.40	.20	--	--	--	--
10	6	5	4	2	.52	.43	.78	.25	.41	.36	.34	.25
25	10.8	9.3	8.5	6.3	.43	.37	.34	.25	.35	.32	.31	.25
50	19.1	17.0	15.9	12.5	.38	.34	.32	.25	.32	.30	.29	.25
100	34.6	31.6	30.0	25.0	.35	.32	.30	.25	.30	.29	.28	.25
500	147.1	140.4	136.9	125.0	.30	.28	.27	.25	.27	.27	.26	.25
1,000	281.4	272.0	267.0	250.0	.28	.27	.27	.25	.27	.26	.26	.25
2,000	544.6	531.4	524.3	500.0	.27	.27	.26	.25	.26	.26	.26	.25
10,000	2,600.4	2,570.7	2,554.9	2,500.0	.26	.26	.25+	.25	.26	.25+	.25+	.25

Table E-3. CIRCUIT-SHARING ECONOMIES WHEN PROBABILITY OF USE IS .5

NUMBER OF USERS	NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE N USERS WITH A GRADE OF SERVICE OF:				AVERAGE NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE N USERS WITH A GRADE OF SERVICE OF:				NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE AN ADDITIONAL USER WITH A GRADE OF SERVICE OF:			
(N)	P01	P05	P10	P50	P01	P05	P10	P50	P01	P05	P10	P50
2	2	2	2	1	1.00	1.00	1.00	.50	--	--	--	--
3	3	3	3	1	1.00	1.00	1.00	.33	--	--	--	--
4	4	4	3	2	1.00	1.00	.75	.50	--	--	--	--
5	5	4	4	3	1.00	.80	.80	.60	--	--	--	--
10	8	8	7	5	.82	.71	.65	.50	.68	.63	.60	.50
25	17.8	16.1	15.2	12.5	.71	.65	.61	.50	.61	.58	.56	.50
50	32.7	30.3	29.0	25.0	.65	.61	.58	.50	.58	.56	.55	.50
100	61.2	57.7	55.9	50.0	.61	.58	.56	.50	.56	.54	.53	.50
500	275.6	267.9	263.8	250.0	.55	.54	.53	.50	.53	.52	.51	.50
1,000	536.3	525.5	519.7	500.0	.54	.53	.52	.50	.52	.51	.51	.50
2,000	1,051.6	1,036.3	1,028.7	1,000.0	.53	.52	.51	.50	.51	.51	.51	.50
10,000	5,116.0	5,081.1	5,063.5	5,000.0	.51	.51	.51	.50	.50+	.50+	.50	.50

Table E-4. CIRCUIT-SHARING ECONOMIES WHEN PROBABILITY OF USE IS .75

NUMBER OF USERS	NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE N USERS WITH A GRADE OF SERVICE OF:				AVERAGE NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE N USERS WITH A GRADE OF SERVICE OF:				NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE AN ADDITIONAL USER WITH A GRADE OF SERVICE OF:			
(N)	P01	P05	P10	P50	P01	P05	P10	P50	P01	P05	P10	P50
2	2	2	2	2	1.00	1.00	1.00	1.00	--	--	--	--
3	3	3	3	2	1.00	1.00	1.00	.67	--	--	--	--
4	4	4	4	3	1.00	1.00	1.00	.75	--	--	--	--
5	5	5	5	4	1.00	1.00	1.00	.80	--	--	--	--
10	9	9	9	8	.91	.93	.88	.75	.91	.86	.84	.75
25	23.3	21.8	21.0	18.8	.93	.87	.84	.75	.85	.82	.81	.75
50	44.1	42.0	40.9	37.5	.88	.84	.82	.75	.82	.80	.79	.75
100	84.6	81.6	80.0	75.0	.85	.82	.80	.75	.80	.79	.78	.75
500	397.1	390.4	386.9	375.0	.80	.78	.77	.75	.77	.77	.76	.75
1,000	781.4	772.0	767.0	750.0	.78	.77	.77	.75	.77	.76	.76	.75
2,000	1,554.6	1,531.4	1,524.3	1,500.0	.77	.77	.76	.75	.76	.76	.76	.75
10,000	7,600.0	7,570.7	7,554.9	7,500.0	.76	.76	.75+	.79	.76	.75+	.75+	.75

Table E-5. CIRCUIT-SHARING ECONOMIES WHEN PROBABILITY OF USE IS .9

NUMBER OF USERS	NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE N USERS WITH A GRADE OF SERVICE OF:				AVERAGE NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE N USERS WITH A GRADE OF SERVICE OF:				NUMBER OF SHARED CIRCUITS REQUIRED TO PROVIDE AN ADDITIONAL USER WITH A GRADE OF SERVICE OF:			
(N)	P01	P05	P10	P50	P01	P05	P10	P50	P01	P05	P10	P50
2	2	2	2	2	1.00	1.00	1.00	1.00	--	--	--	--
3	3	3	3	3	1.00	1.00	1.00	1.00	--	--	--	--
4	4	4	4	4	1.00	1.00	1.00	1.00	--	--	--	--
5	5	5	5	5	1.00	1.00	1.00	1.00	--	--	--	--
10	10	10	10	9	1.00	1.00	1.00	.90	1.00	.98	.96	.90
25	25	25	23.9	22.5	1.00	1.00	.96	.90	.97	.95	.94	.90
50	49.4	48.0	47.2	45.0	.99	.96	.94	.90	.95	.94	.93	.90
100	96.5	94.4	93.3	90.0	.97	.95	.94	.90	.93	.93	.92	.90
500	465.1	460.5	458.1	450.0	.93	.92	.92	.90	.92	.91	.91	.90
1,000	921.6	915.1	911.6	900.0	.92	.92	.91	.90	.91	.91	.91	.90
2,000	1,830.8	1,821.6	1,816.7	1,800.0	.92	.91	.91	.90	.91	.90+	.90+	.90
10,000	9,069.4	9,048.9	9,037.9	9,000.0	.91	.90+	.90+	.90	.90+	.90+	.90+	.90

Table E-5, 50 users would require over 49 circuits to achieve the P01 grade of service, which means a network would be of little value.

In summary, the advantages of a network depend upon the number of users to be included, the grade of service required and finally, the intensity of use of the individual users. It should be noted that this presentation is only illustrative in nature and does not attempt to capture all the complexities that would be necessary in a traffic engineering study to determine the optimal configuration of service. It should also be emphasized that a network arrangement which is adequate at one level of use may prove completely inadequate if the probability of use suddenly increases for all users, as well might be the case in an emergency situation such as a war.

2. Explanation of Methodology

This section explains the derivation of Tables E-1 through E-5. The following symbols will be used:

P = probability of use by one user (the same for all users)
N = number of potential users
L = number of circuits
y = number of standard deviations away from the mean in a normal distribution

It is assumed that the probability of use is the same for all users and that the probability is independent among users. The standard measure of congestion is the probability that there will be excess demand for the facilities (i.e., that a call attempt will be blocked). This measure is termed the grade of service.

The probability that the number of users is less than or equal to the number of circuits can be determined directly from the binomial probability distribution. This procedure becomes unwieldy, however, when the number of users (N) becomes large.

Fortunately, as N increases, the normal probability distribution can be used to approximate the binomial. This is done here when N exceeds 10, i.e., when N is greater than or equal to 25.

For the binomial distribution (which is appropriate for this problem), the mean is equal to PN, the expected number of calls attempted, while the standard deviation is given by $\sqrt{NP(1-P)}$. Using the normal distribution to approximate the binomial, the number of standard deviations any particular outcome departs from the mean is given by the normalized form:

$$y = \frac{L + \frac{1}{2} - PN}{\sqrt{P(1-P)N}} .$$

For example, if P = .5 and N = 100, the expected number of attempted calls would be 50. If the number of lines is equal to 60, we would like to find the probability that 60 or fewer calls would be made during the period in question. Calculating y, we find:

$$\frac{60 + \frac{1}{2} - (.5)(100)}{\sqrt{(.5)(.5)100}} = \frac{10.5}{5} = 2.1 .$$

(The $\frac{1}{2}$ is added to L to include one-half the distance between L and L + 1 since we are approximating a discrete distribution with a continuous one.) The probability that the number of calls will be less than or equal to 2.1 standard deviations above the mean (which can be found in a cumulative normal distribution table) is .982. This tells us that with 100 potential users (each with a probability of use of .5) 60 or fewer will attempt to use the service during the given period with a .982 probability, i.e., congestion will be experienced less than two percent of the time.

Using this technique, the probability of congestion can be calculated as a function of L, P and N. This form also makes

possible the calculation of the number of circuits necessary to achieve a particular probability that the system will be congestion-free. To find the number of lines necessary to serve various numbers of users at a particular level of the grade of service, we would find from the tables the y value for the corresponding probability of non-congestion, say .95. This will be labeled $y_{.95}$ and equals 1.645. This is then put into the normalized equation:

$$y_{.95} = \frac{L + \frac{1}{2} - PN}{\sqrt{P(1-P)N}} .$$

Solving this equation for L, we find:

$$L = \sqrt{P(1-PN}\; y_{.95} + PN - \frac{1}{2} .$$

Using this result, the number of circuits necessary to accommodate the users can be seen to be a function of P, N and y (which relate to the grade of service desired). The number of circuits necessary for various numbers of users for any given y value and for a given probability of use can be calculated in a straightforward way.

This form also makes possible the calculation of the average number of circuits necessary per user. This is given by the following:

$$\text{Average number of circuits per user} = \frac{L}{N} = \frac{\sqrt{P(1-P)}}{\sqrt{N}}\, y + P - \frac{1}{2N} .$$

The number of extra lines necessary to accommodate an additional user (holding the grade of service constant) can be found by taking the first derivative of the normalized equation for L and this yields:

Extra circuits required for the marginal user =

$$\frac{dL}{dN} = \frac{1}{2}\,\frac{\sqrt{P(1-P)}}{\sqrt{N}}\, y + P .$$

It can be seen that both L/N and dL/dN will approach P as N becomes large.

It should be remembered that the normal approximation is appropriate only when N becomes fairly large. It should also be noted that this analysis is illustrative in nature and is not intended to substitute for more detailed traffic engineering studies concerning the advantages of networking and similar arrangements.

APPENDIX F

DETERMINATION OF COSTS AND SUBSCRIBER CHARGES

DETERMINATION OF COSTS AND SUBSCRIBER CHARGES

A. DCS FUNDING

The Defense Communications System (DCS) and its component systems are managed by the Defense Communications Agency (DCA). Funding, engineering, and day-to-day operation of the DCS involves both DCA and the military departments, within DCA's overall management direction. The relationships among DCA and the military departments are complex, with each of these agencies playing more than one role. DCA's primary role is to act as supplier of long-haul communications services to the military departments. The primary role of the military departments (in the present context) is that of customer, obtaining required services from DCA. But to some extent, these roles are also reversed. DCA acts as a prime contractor, arranging for the military departments to provide a major share of the required resources and services. Similarly, the military departments act as suppliers, producing communications services for DCA (and hence for their fellow military departments).

The flow of funds within the DCS reflects the complexity of these relationships. Through a planning and review process involving the military departments, the Joint Chiefs of Staff (JCS), and the Assistant Secretary of Defense (ASD(C^3I)), DCA establishes the DCS Five Year Program. This Five Year Program details planned expenditures for the DCS, by project and appropriation, and indicates responsibility for obtaining the required funds. Military departments and DCA request the required funds through the usual DoD Planning, Programming, and

Budgeting process. Funds are appropriated by Congress, and apportioned to the particular components.

Except for O&M, funds are usually obligated by the component to which they are apportioned. For O&M, expenditure is complicated by the existence of the Communications Services Industrial Fund (CSIF). The CSIF is a working-capital fund managed by DCA. DECCO (Defense Commercial Communications Office) uses the CSIF to finance commercial leases for defense communications, including both DCS and non-DCS communications. The CSIF is then reimbursed by the organizations ordering the services.

In the case of the DCS common-user systems, the CSIF is used to finance commercial leases, and to reimburse the military departments for some of the O&M expenses they incur while operating and maintaining common-user facilities. In turn, the CSIF is reimbursed through the payment of subscriber charges by organizations using common-user services. The subscriber charges are calculated by DCA so that the CSIF can breakeven.

The O&M budget requests of the military departments reflect their dual roles as customers and suppliers of DCS services. That is, the requests include funds with which to pay subscriber charges for the use of common-user systems, as well as funds with which to provide operational support to various DCS systems. Indeed, in many instances, a military department is the primary user of systems it operates.

These relationships can be illustrated with the help of Tables F-1, F-2, F-3, and F-4. These tables provide summary information on the DCS budget for FY78. As indicated on Table F-1, DCA itself controls only $79,782,000, or 10.1 percent of the total DCS budget. Of the DCA budget, $58,850,000 or 73.8 percent covers headquarters support expenditures (see Tables F-3 and F-4). DCA itself controls only 8.9 percent of R&D funds, and 1.4 percent of the procurement appropriations

Table F-1. DCS BUDGET, BY APPROPRIATION AND COMPONENT (FY78, in $000s)

	R&D	Procurement	Military Construction	O&M	Military Personnel	Total $'s	# of Personnel Civilian	# of Personnel Military
Army	$ 7,882	$ 86,955		$106,681	$ 48,585	$250,103	# 1,460	# 4,372
Navy		5,583		58,407	14,269	78,259	411	1,317
Air Force	66,295	94,067		136,643	55,133	352,138	453	4,940
DCA	8,625	2,753		50,000	18,404	79,782	1,076	1,041
NSA	14,470	1,664	436	4,917		21,487		
DLA				6,403		6,403		
Other				1,114		1,114		
TOTAL	$97,272	$191,022	$436	$364,165	$136,391	$789,286	3,400	11,670

Table F-2. DCS BUDGET, BY APPROPRIATION AND PROJECT (FY78, in $000s)

DCS Project Category	Procurement	Military Construction	RDT&E	O&M	Military Personnel	Total $'s	# of Personnel Civilian	# of Personnel Military
Leased Communications				$240,595		$240,595		
Engineering and Installation				17,649	13,345	30,994	412	874
Headquarters Support				48,546	23,977	72,523	1,410	1,299
AF Area Operations				1,643	4,162	5,805	41	326
Station Operations				55,732	94,907	150,639	1,537	9,171
AUTOVON	2,350					2,350		
AUTODIN	6,625					6,625		
Integrated AUTODIN SYSTEM			10,147			10,147		
AUTOSEVOCOM I	3,751					3,751		
Secure Voice Improvement Program			10,747			10,747		
DCS Architectures and Integration			2,913			2,913		
Other Projects (Switched)			661			661		
Defense Satellite Communications System II	132,346	436	1,565			134,347		
Defense Satellite Communications System III			64,822			64,822		
Defense Satellite Communications System (Future)			5,864			5,864		
Terrestrial Transmission	20,070		2,618			22,688		
Technical Evaluation	400					400		
Commercial Equipment Evaluation			280			280		
R&D: Long-Line Leases			1,289			1,289		
Survivability			871			871		
System Control	19,425		2,120			21,545		
Other Projects (Support)	6,055					6,055		
Discrepancy			-6,625			-6,625		
Total	$191,022	$436	$97,272	$364,165	$136,391	$789,286	3,400	11,670

Table F-3. DCS O&M BUDGET, BY PROJECT AND COMPONENT
(FY78, in $000s)

	Leased Communications	Engineering and Installation	Headquarters Support	AF Area Operations	Station Operations	Total
Army	$ 61,687	$12,540	$ 5,990		$26,464	$106,681
Navy	47,432	3,202	959		6,814	58,407
Air Force	109,488	1,907	1,151	1,643	22,454	136,643
DCA	9,554		40,446			50,000
NSA	4,917					4,917
DLA	6,403					6,403
Other	1,114					1,114
Total	$240,595	$17,649	$48,546	$1,643	$55,732	$364,165

Table F-4. DCS MILITARY PERSONNEL BUDGET, BY PROJECT AND COMPONENT

	Leased Communications	Engineering and Installations	Headquarters Support	AF Area Operations	Station Operations	Total
Army		$11,958	$ 3,459		$33,168	$ 48,585
Navy			135		14,134	14,269
Air Force		1,387	1,979	4,162	47,605	55,133
DCA			18,404			18,404
NSA						
DLA						
Other						
Total		$13,345	$23,977	$4,162	$94,907	$136,391

for the DCS. Table F-2 provides a breakdown of these appropriations by project category.

DCA directly controls 13.7 percent of the DCS O&M funds, but indirectly controls a substantially larger portion. As indicated on Table F-3, $240,595,000 is spent on leased communications. While 96.0 percent of leased-communications appropriations are controlled by components other than DCA, virtually all of these funds are spent through DECCO and the CSIF. Further, a substantial portion (at least $145,468,000 or 60.5 percent) of leased-communications appropriations are for subscriber charges to common-user systems managed by DCA. And DCA controls lease expenditures for common-user systems. The remainder of the $240,595,000 is spent at user direction for leased access lines to the common-user networks, and for leased dedicated circuits. The total annual revenue of the CSIF is estimated at $427,900,000 and thus includes a substantial amount of leased services classified as non-DCS.

B. REVIEW BY SYSTEM

The discussion now turns to a brief review of the ways in which costs are incurred and subscriber charges are calculated for the various DCS systems.

1. AUTODIN

The AUTODIN backbone is a network of 16 Automatic Switching Centers (ASCs) and over 46 Interswitch Trunks (ISTs). The ASCs are primarily computers which accept, store, and dispatch messages to appropriate trunks and access lines. In the long run (when all costs are variable), ASC costs depend on the number of subscribers and the timing and amount of message traffic. But from year to year, ASC costs are largely fixed, while the number and cost of ISTs are adjusted in light of the timing and volume of message traffic. As is discussed later in

this paper, there is substantial excess capacity at the ASCs, but not with regard to the ISTs.

In CONUS and Hawaii, the Automatic Switching Centers (ASCs) are leased. They are located on military bases, operated by the military departments, but maintained by contractor personnel. Overseas ASCs are government-owned, and are operated and maintained by the military departments. Interswitch Trunks (ISTs) are leased within CONUS and may be owned or leased overseas.

The Communications Services Industrial Fund (CSIF) is used to finance certain recurring backbone expenses, including:

- ASC lease and contract maintenance costs;
- Interswitch Trunk leases;
- Reimbursement to the military departments for O&M expenses (primarily civilian pay and supplies) incurred at ASCs;
- DECCOs expenses in operating the CSIF, assessed at 1-1/2 percent of the amount financed.

These costs are recovered for the CSIF by means of subscriber charges to AUTODIN users. In addition, the CSIF finances lease costs associated with subscriber access lines, and is reimbursed by subscribers for the amounts involved, plus the DECCO overhead charge.

Industrially funded AUTODIN backbone expenses are estimated to be as follows:

Automatic Switching Centers	$39,383,000
Interswitch Trunks	1,960,000
AUTOVON Interconnects	1,123,000
DECCO Overhead	547,000
Total Backbone Expense	$43,013,000 .

Clearly, the bulk of these expenses are associated with the ASCs.

Other economic costs (both recurring and non-recurring) of providing the AUTODIN backbone are not financed by the CSIF. These include:

- Depreciation on government-owned ASCs and ISTs;
- Research and development;
- Cost of military personnel associated with ASC O&M;
- O&M on government-owned ISTs;
- DCA overhead and system management costs (other than DECCO).

These costs are financed by direct appropriations to the military departments and DCA.

DCA directly controls the funds appropriated to it, and the commercial contracts financed by the CSIF for the AUTODIN backbone. DCA influences other backbone expenditures by virtue of its overall management role. That is, military departments are tasked by OSD to support AUTODIN in specific geographic areas. That tasking includes providing appropriated funds adequate to maintain service standards and procedures established by DCA.

In order to calculate AUTODIN subscriber charges, each type of service is assigned a particular number of weighted units. The total number of weighted units is forecasted for the fiscal year in question, based on requirements estimates made by the various defense components. (Thus, these estimates are made before subscriber charges are known.) A charge per weighted unit is determined by dividing the total number of weighted units into a forecast of CSIF expenses for the AUTODIN backbone. The subscriber charge for a particular service is calculated by multiplying the charge per weighted unit times the number of weighted units assigned to that service.

Subscriber charges for regular AUTODIN services vary with the line-speed capabilities of subscriber access lines. They do not vary with destination, precedence, timing, or message

volume. Weighted units and subscriber charges for FY80 are listed on Table F-5.

Table F-5. SUBSCRIBER CHARGES FOR AUTODIN SERVICE (FY80)

Line-Speed of Access Line	Number of Weighted Units	AUTODIN I Monthly Rates	AUTODIN II Monthly Rates
Very High Speed			
56,000 bps	(22)	(Not Available)	$5,368
19,200 bps	(19)	(Not Available)	4,636
9,600 bps	(16)	(Not Available)	3,904
High Speed			
4,800 bps	(14)	$6,650	3,416
2,400 bps	(12)	5,700	2,928
Medium Speed			
1,200 bps	(9)	4,275	2,196
600 bps	(6)	2,850	1,464
Low Speed			
300 bps & lower	(3)	1,425	732

Subscriber charges for the Query/Response service are calculated by an *ad hoc* method, designed to make this service competitive with services users could order from other sources. These subscriber charges vary with the line-speed capabilities of access lines, with the number of destinations authorized, and with the size of calling area required to include all of the authorized destinations. Query/Response charges for FY80 are listed in Table F-6.

Table F-6. SUBSCRIBER CHARGES FOR AUTODIN QUERY/RESPONSE SERVICE

(FY80)

Line-Speed of Access Line	Number of Terminals/ Hosts Accessed	Area[a]	Area Plus[b]	Worldwide
High Speed				
(2400, 4800 bps)	1	$ 500	$1,500	$2,500
	2	600	1,600	2,600
	3	700	1,700	2,700
	4	800	1,800	2,800
	5	900	1,900	2,900
	6	1,000	2,000	3,000
Medium Speed				
(600, 1200 bps)	1	300	900	1,500
	2	400	1,000	1,600
	3	500	1,100	1,700
	4	600	1,200	1,800
	5	700	1,300	1,900
	6	800	1,400	2,000
Low Speed				
(75, 150, 300 bps)	1	100	300	500
	2	200	400	600
	3	300	500	700
	4	400	600	800
	5	500	700	900
	6	600	800	1,000

[a]Area Service includes one of the following:

(1) CONUS (excluding Hawaii)
(2) Pacific (including Hawaii)
(3) Europe

[b]Area Plus Service includes one of the following:

CONUS to Europe or Europe to CONUS
CONUS to Pacific or Pacific to CONUS

2. ARPANET

ARPANET is a network consisting of some 72 switching nodes (i.e., minicomputers and interface equipment), interconnected by wideband (i.e., 50,000 bits per second) Interswitch Trunks (ISTs). The network is monitored and controlled from a Network Control Center. The switching node costs vary directly with the number of switching nodes, and indirectly with the number of subscribers and the timing and volume of data traffic.

ARPANET is managed by DCA with the assistance of the ARPANET Sponsor's Group, which provides advice on the quality of network services. DCA contracts with outside firms for many management services, including operation of the Network Control Center, installation and maintenance of equipment, development and maintenance of computer software, and provision of directories, handbooks and manuals. The ISTs are leased through DECCO. The switching nodes are purchased by organizations called sponsors. The sponsors must follow ARPANET procedures and standards, but they decide what user terminals and computers may be connected to ARPANET by means of their switching node. User access lines are leased through DECCO.

The Communications Services Industrial Fund finances recurring ARPANET backbone costs, including the following for FY80:

Engineering Support Contract	$1,837,000
Information Support Contract	225,000
Interswitch Trunks	1,708,000
DECCO Overhead	56,550
Total Backbone Expense	$3,826,550

These costs are recovered by subscriber charges, calculated by dividing the backbone expenses by the number of switching nodes. For FY80, the subscriber charge amounts to $6,496 per month per

switching node. The charge is assessed against the node sponsor, as are CSIF costs related to the lease of access lines by some users of the switching node. It is up to the node sponsor to determine any arrangements for reimbursement of his costs by the individual users.

The subscriber charges do not include depreciation related to the switching node equipment. Since that equipment costs in excess of $100,000 per node, depreciation probably amounts to well in excess of $500,000 per year for the network.

3. WIN

WIN, or the Worldwide Military Command and Control System Intercomputer Network, is modeled to a large extent after ARPANET. It is being implemented now, and will eventually consist of 22 switching nodes, two technical control centers, and appropriate ISTs with line-speed capabilities of 50,000 bits per second. Subscriber charges will be initiated in FY81, to recover recurring backbone expenses financed by the CSIF. Current plans call for charges based on connectivity, rather than on the timing or amount of usage.

4. AUTODIN II

This network is similar to (and will eventually incorporate) ARPANET and WIN. It will initially consist of 4 switching nodes, 10 ISTs with line-speed capabilities of 56,000 bits per second, and a network control center. Additional nodes and ISTs will be added as needed.

Switches will be leased both in CONUS and overseas. They will be operated by the military departments, and maintained by contractor personnel. ISTs will be leased. Engineering and programming support will be obtained by contract.

The CSIF will be used to finance contracts for IST and switch leases, for maintenance and engineering support, for

military department expenses associated with operating the switching centers, and for DECCO overhead. Subscriber charges will be used to recover these costs, and will be calculated using the same methodology as that employed for AUTODIN itself. These subscriber charges vary with the line-speed capabilities of subscriber access lines, but not with the destinations called, precedence levels, or the timing and volume of usage. The weighted units and subscriber charges for FY80 are listed on Table F-5 above. The weighted units for various line-speeds are designed to favor subscribers at the higher line-speeds.

The costs of military personnel to operate the switching centers, and of DCA overhead (other than DECCO), are funded by direct appropriations and are not reflected in the subscriber charges. Also, subscribers will pay certain costs in order to interface with the switching centers, and will lease access lines through DECCO.

5. AUTOVON

AUTOVON is a network of some 75 switches, interconnected by over 8,600 ISTs. The number and cost of AUTOVON switches depends largely on the number of subscribers. On the other hand, the number and cost of ISTs depends largely on the timing and volume of calls.

AUTOVON switches in CONUS and Hawaii are leased, and are operated and maintained by contractor personnel. Lease charges vary with the number of subscribers and switches. Overseas, AUTOVON switches are government-owned, and are operated and maintained by the military departments. The ISTs are leased in CONUS, and are both leased and government-owned overseas.

As system manager, DCA determines funding requirements for AUTOVON, and obtains OSD approval. The CSIF is used to finance:

- the costs of switch and IST leases;
- contracts for switch operation and maintenance;

- military department costs of operating and maintaining AUTOVON switches (other than military personnel costs);
- DECCO overhead costs.

These backbone costs are reimbursed to the CSIF by means of subscriber charges to AUTOVON users. The CSIF is also used to finance lease charges for individual subscriber access lines and is reimbursed by subscribers for the lease charge plus 1-1/2 percent for DECCO overhead. The decision to subscribe and the choice of the number of access lines is the responsibility of the subscriber.

For FY78, the AUTOVON backbone costs financed by the CSIF are as follows:

Switching Centers	$ 6,424,000
Interswitch Trunks	79,880,000
DECCO Overhead	1,291,000
	$87,595,000 .

Clearly, the bulk of AUTOVON backbone costs are associated with ISTs.

The CSIF is not used to finance certain other costs of providing AUTOVON service. These include:

- depreciation on government-owned switches and ISTs;
- military personnel costs associated with the operation of AUTOVON switches;
- O&M costs associated with operation of ISTs;
- DCA overhead associated with managing AUTOVON.

These costs are funded by direct appropriation to either DCA or the military department tasked by OSD with responsibility. Depreciation is an economic cost and does not affect cash flow, except at the time that the depreciating item must be replaced. At that time, procurement of the required equipment is funded by appropriation.

AUTOVON subscriber charges vary with a number of parameters:

- maximum geographic calling area,
- maximum precedence authorization,
- directionality of access lines,
- conditioning of IST.

To calculate subscriber charges, weighted units are assigned to the various services. A regular, two-way voice line is assigned 1 weighted unit for routine precedence, 2 for priority, 3 for immediate, and 4 for flash. An access line capable only of sending calls is assigned double the number of units assigned to a two-way line of the same precedence level. There is no subscriber charge for access lines authorized only to receive calls. A subscriber authorized to use special ISTs (overseas) which are conditioned suitable for data signals is assigned double the weighted units that would be assigned for only voice-conditioned ISTs.

The total number of weighted units is forecasted based on the estimates of the defense components as to their requirements for the various services. Charges per weighted unit are determined for each calling area, by dividing forecasts of CSIF backbone expenses for each area by corresponding forecasts of weighted units. Subscriber charges for the various services in each area are determined by multiplying the charge per weighted unit by the number of weighted units assigned to the service in question. The AUTOVON subscriber charges for FY80 are listed on Table F-7.

6. AUTOSEVOCOM

AUTOSEVOCOM is a network in its own right, but relies primarily on AUTOVON to supply its long-distance trunks. AUTOSEVOCOM consists of some 30 automatic and 101 manual switches. Some 1,460 subscribers are connected to these switches, and an additional 276 AUTOSEVOCOM subscribers are connected directly to AUTOVON switches. Each subscriber has a vocoder to encrypt

Table F-7. SUBSCRIBER CHARGES FOR AUTOVON SERVICE (FY80)

Type of Service and Pre-emption Capability[a]	MAXIMUM CALL AREA									
	LOCAL		AREA			AREA +			GLOBAL	
Phone; Phone/Secure Voice; Switch Facility, Secure Voice; and PBX (Two-Way Service)	EUR	PAC	CONUS	EUR	PAC	CONUS TO EUR AND EUR TO CONUS	CONUS TO PAC AND PAC TO CONUS	CONUS TO CARIB AND CARIB TO CONUS		CADIN[b]
Flash (4)	$ 80	$ 708	$ 1,220	$ 160	$1,412	$ 2,476	$ 3,116	$ 1,592	$ 4,744	$ 1,200
Immediate (3)	60	531	915	120	1,059	1,857	2,337	1,194	3,558	900
Priority (2)	40	354	610	80	706	1,238	1,558	796	2,372	600
Routine (1)	20	177	305	40	353	619	779	398	1,186	300
Phone/Data and PBX (Send Only) Service										
Flash (8)	160	1,416	2,440	320	2,824	4,952	6,232	3,184	9,488	2,400
Immediate (6)	120	1,062	1,830	240	2,118	3,714	4,674	2,388	7,116	1,800
Priority (4)	80	708	1,220	160	1,412	2,476	3,116	1,592	4,744	1,200
Routine (2)	40	354	610	80	706	1,238	1,558	796	2,372	600
Monthly Rate Per Weighted Unit (1)	20	177	305	40	353	619	779	398	1,186	300

[a]Weighted Units Shown in Parentheses.
[b]Applicable only to Air Force

his calls, and an access line to the appropriate switch. In turn, there are 247 access lines connecting AUTOSEVOCOM switches to the AUTOVON backbone. In addition to using the AUTOVON trunks, AUTOSEVOCOM has 47 wideband trunks of its own. Finally, DCA provides 5 AUTOSEVOCOM Network Assessment Facilities.

The AUTOSEVOCOM switches are government-owned and are operated and maintained by the military departments (except that the Pentagon switch is leased and contractor-maintained). AUTOSEVOCOM access lines and ISTs, and AUTOVON access lines, are leased in CONUS and both leased and government-owned overseas. AUTOSEVOCOM is assessed regular AUTOVON subscriber charges for its AUTOVON access lines. The vocoder encryption equipment is government-owned.

While DCA is responsible for overall management and operational control, AUTOSEVOCOM backbone costs are not pooled, and there are no AUTOSEVOCOM subscriber charges. Particular military departments are responsible for all funding required for particular switches, including:

- procurement of switch and related equipment,
- operation and maintenance of switch,
- leased subscriber charges, and other government costs associated with AUTOSEVOCOM access to AUTOVON,
- lease charges for AUTOSEVOCOM ISTs,
- research and development of vocoder equipment.

DCA itself funds management overhead out of direct appropriations. Individual AUTOSEVOCOM subscribers are responsible for their own vocoders and access lines. In some cases, the military department funding a switch charges a portion of its costs to individual subscribers, but this is rare. And any services financed by the CSIF are directly reimbursed by the organizations ordering those services.

7. ATSS

The Alaska Telephone Switching System consists of 2 switches, 70 intra-Alaska ISTs, and 74 access lines from ATSS to AUTOVON in the lower-48 states. Some 471 subscribers are connected to ATSS switches. In addition, there are 14 access lines from Alaska to AUTOVON (in the lower-48 states) which are wired through ATSS switches, so that they are available to ATSS when not in use by their "owners."

The switches are government-owned, but are operated and maintained by contract. Within Alaska, the ISTs are leased. The AUTOVON access lines are both leased and government-owned.

The CSIF is used to finance a portion of recurring ATSS costs, and is reimbursed by ATSS subscriber charges. Costs included in the ATSS backbone include:

- 50 percent of the lease charges for access lines between Alaska and AUTOVON,
- lease charges for intra-Alaska ISTs,
- contract charges for switch O&M,
- DECCO overhead costs.

Subscriber charges are calculated by dividing these costs by the number of ATSS subscribers. For FY80 this amounts to a charge of $893.20 per ATSS subscriber. Of course, subscribers are responsible for their own access lines.

For FY78, ATSS backbone expenses recovered by means of subscriber charges are as follows:

Intra-Alaska Trunks	$1,120,000
AUTOVON Access Lines	1,422,000
Switch O&M	2,532,000
	$5,074,000

There are a number of economic costs of providing ATSS services which are not reflected in subscriber charges:

- depreciation of switches and related equipment,
- 50 percent of the lease charges for AUTOVON access lines,
- subscriber charges for the use of the AUTOVON backbone,
- depreciation of government-owned AUTOVON access lines,
- DCA overhead for management services.

8. Dedicated Circuits

Dedicated circuits are provided to users in the same ways that common-user trunks and access lines are provided. A ready-to-use, end-to-end circuit may be provided by a commercial lease. Alternatively, the circuit may be derived wholly or in part within the DCS.

Deriving a circuit involves the creation of a transmission path, which may require cables or broadcast equipment (e.g., microwave, high-frequency radio, tropospheric scatter, satellite). It also usually involves the use of multiplex equipment to derive a number of individual channels from each transmission path. Within the DCS, the multiplexers and the transmission paths may both be leased or both be owned. Or, leased multiplexers may be used with owned transmission paths, or *vice versa*.

The provision of DCS circuits (to dedicated users as well as common-user systems) is managed by DCA. In coordination with the DCS Five Year Program, the transmission system is planned and funding and operational responsibilities are tasked to the various defense components.

Requests for individual circuits are forwarded by the requesting agency (after validation and certification as discussed above) to an appropriate DCA area office, or in some cases to DCA headquarters. An allocation engineer reviews the request to determine the best way of satisfying it. He checks for unused capacity in existing systems, and allocates suitable channels to the requesting users. In some cases, the request is forwarded to the multiplex division to determine whether a

new multiplexer system should be established. If the application is suitable for satellite transmission, the allocation engineer may be able to assign a DSCS (Defense Satellite Communications System) channel. In some cases, the user may forward his request directly to the satellite office. The allocation engineer may assist the user in specifying a lease requirement. All lease requirements are forwarded to DECCO to satisfy. DECCO fulfills the requests so as to take advantage of available volume discounts (e.g., TELPAK). That is, DECCO routes and combines circuit requests so as to increase the number of circuits leased between particular destinations.

When a user is allocated a circuit provided by government-owned facilities, usually no charges are assessed against that user; that is, the user does not pay for the economic cost of the circuit, including: depreciation of government-owned facilities, costs of operating and maintaining those facilities, DCA overhead for managing those facilities.

When the circuit request is satisfied by a leased circuit, the lease is financed through the CSIF. The user is charged the cost of the lease, plus the DECCO overhead. Individual lease charges within CONUS are calculated as fixed monthly charges per channel (i.e., termination charges) plus inter-exchange channel (i.e., IXC) charges based on the airline mileage between origin and destination. The mileage rate declines as distance increases. Charges vary depending on bandwidth, conditioning, and population density of origin and destination locations.

If the lease is provided under the TELPAK volume discount, DECCO leases a large amount of transmission capacity between particular points. Lease charges are calculated as a flat rate per mile for the IXC, plus termination charges which depend on what types of circuits are ordered from the transmission capacity leased. The mileage rate (for a given type of circuit) is lower for larger amounts of transmission capacity. Capacity

can be ordered only in certain fixed amounts, and it is possible (up to a point) to order capacity which is not used and still lower the total cost of the channels which are used (as compared with the cost of leasing those channels individually).

To reimburse the CSIF for these charges, TELPAK users are charged 56 cents per mile for a voice-equivalent IXC, plus 1-1/2 percent for DECCO overhead. The IXC rate for teletype circuits is 28 cents per mile, and wideband circuits have IXC charges which are appropriate multiples of 56 cents per mile (depending on the bandwidth obtained). The 56 cents per mile charge is calculated as the average IXC charge per mile paid by DECCO for all of its TELPAK leases. Since actual TELPAK IXC rates can be as low as 38 cents per mile, some users are charged more, and some less, than the actual charge under their particular TELPAK lease. Average IXC charges exceed 38 cents per mile, in part because some leases involve less capacity than the maximum which could be leased, and in part because some amount of leased capacity is not used.

There are also a number of common-user multiplex systems managed by DCA to provide dedicated circuits. These systems incur certain lease and contract charges which are financed by the CSIF, which is reimbursed by means of subscriber charges.

As noted above, multiplexing is the derivation of a number of communications channels from a particular transmission path. This permits realization of the economies of scale available from building transmission paths with relatively great capacity. When government-owned trunks are multiplexed (by means of either owned or leased multiplex equipment), the advantage lies in realizing these scale economies. When leased trunks are multiplexed (by either owned or leased equipment), the scale economies have already been realized by the common carrier. The advantage to multiplexing lies in the fact that lease charges reflect substantial discounts for circuits of greater capacity. That is, the common carrier does not pass on the savings that it

realizes from multiplexing, so that the DCS can reduce costs by doing its own multiplexing.

A multiplex system consists primarily of a transmission path (i.e., trunk); time-division multiplex equipment, modems, and related equipment at each end of the trunk; and some amount of operations and maintenance support. The sources of these inputs for the various DCS multiplex systems are listed in Table F-8. As indicated, there is considerable variety with respect to the use of commercial and government resources.

The systems shown embody several different multiplex technologies. VFCTs (Voice Frequency Carrier Telegraphs) can derive up to 16 teletype channels (up to 75 bps) from a voice-equivalent circuit conditioned to carry 1,200 bps. On a voice-equivalent channel conditioned to carry 2,400 bps, VFCTs can be used to derive up to 24 teletype channels. Channel-packing equipment is used to derive data channels from a voice-equivalent circuit operating at 9,600 bps (7,200 bps for European circuits). There can be 4 channels sending 2,400 bps, 8 channels sending 1,200 bps, and similar subdivisions down to and including 75 bps for teletype. The way the 9,600 bps capacity is subdivided determines the type of additional equipment required. The 1.544 mbps systems derive up to 24 voice-equivalent channels from a trunk capable of 1.544 mbps. The user signals are digitized and encrypted for transmission. The WAWS (Washington Area Wideband System) derives 8 channels with capacities of 1.544 mbps from trunks with capacities of 12.928 mbps.

Subscriber charges are used to reimburse the CSIF for the multiplex-system costs it finances. These costs include:

- trunk lease charges,
- equipment lease charges,
- contract operations and maintenance,
- DECCO's overhead,
- equipment purchased under the Fast-Payback program.

Table F-8. SOURCE OF INPUTS FOR MULTIPLEX SYSTEMS

Type of System	Type of Input: Trunk	Multiplex and Related Equipment.	Operation and Maintenance
Intra-Europe Channel Packing	Government-owned	Leased	by Contract
Transoceanic Channel Packing	Leased[a]	Leased	by Contract
Transoceanic VFCT	Leased[a]	Government-owned	by Military Department
CONUS Channel Packing	Leased	Leased	by Military Department
CONUS VFCT	Leased	Government-owned	by Military Department
1.544 mbps Systems	Leased	Government-owned[b]	by Military Department
Washington Area Wideband System	Leased	Government-owned	by Contract

[a]In some cases, these trunks may also be government-owned.

[b]This equipment is purchased by the CSIF under the Fast-Payback Program.

The CSIF does not finance, nor do subscriber charges reflect, the following economic costs:

- depreciation on government-owned trunks,
- depreciation on government-owned multiplex and related equipment,
- O&M furnished by the military departments,
- DCA management overhead (other than DECCO).

To calculate subscriber charges, the number of channels which will be used is projected for each multiplex system, usually based on user input. For overseas VFCT systems, reimburseable costs for each route are divided by the projected number of users for that route, to determine the point-to-point subscriber charge. For overseas channel-packing systems, point-to-point subscriber charges are similarly calculated, except

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that reimburseable costs are prorated based on the transmission line-speed of the channels that will be in use. Subscriber charges in CONUS for VFCT and channel-packing systems consist of a flat rate per channel plus a charge per mile based on the airline mileage between origin and destination. The charge per channel is a proration of equipment and termination costs according to the line-speed of the channels which will be used. The charge per mile is a similar proration of channel costs over the channel mileage which will be used. Both parts of the CONUS subscriber charge are averages across all the multiplex systems in CONUS.

Subscriber charges for the 1.544 mbps systems are calculated by prorating reimburseable costs (except for Fast-Payback equipment) across projected in-use channels for each system. The cost of equipment purchased by the CSIF is handled in a number of ways. One method is for the subscriber to continue paying the CSIF the higher charges it paid for the same services prior to going onto a 1.544 mbps system. This continues until the equipment cost is recovered (from the excess of the charge over recurring costs), at which point charges are calculated based only on recurring costs.

Subscriber charges for WAWS are also calculated by prorating reimburseable costs over the projected number of channels which will be used. The reimburseable cost for each route is determined by allocating total costs to routes dependent on the number of WAWS segments included in the route. (That is, to some extent WAWS routes use the same transmission paths.) Initial charges (for FY80) assumed 90 percent utilization. Whereas the charges for other multiplex systems are for a complete circuit, the WAWS charges buy only half of a circuit; that is, the WAWS charges are assessed at each end of the circuit.

The recurring contractor costs for WAWS amount to $2,122,000 for FY80. Total procurement costs for WAWS amounted to $10,915,000. Assuming straight-line depreciation and a ten-year life (for purposes of illustration), depreciation for the government-owned portion of WAWS amounts to $1,091,500 per year. This suggests that subscriber charges based only on recurring costs cover 2/3 rds of annual economic costs.

APPENDIX G

COST OF AUTOVON CONGESTION

COST OF AUTOVON CONGESTION

A. TYPES OF CONGESTION COSTS

There are several different types of costs which result from AUTOVON congestion. First, congestion prevents scarce AUTOVON capacity from being allocated to its highest valued uses. While it is true that the system of precedence attempts to ensure that some circuits are always available to calls of the highest value, it does not succeed in bringing about optimal allocation of AUTOVON circuits among calls of less than the highest value. To the extent that it fails in this attempt (i.e., to the extent that lower value calls are being completed at the expense of higher value calls), the overall value of the service provided by AUTOVON is less than it could be. Even if some of these blocked calls are eventually completed after one or more re-dials, the value of their messages may be reduced by the time delay. Unfortunately, the data needed to estimate the cost of these delays, as well as the cost of the calls never completed, are not available.

Another cost of congestion occurs when a user, unable or unwilling to make the necessary re-dials to complete his calls, resorts to an alternative telephone service (e.g., a commercial carrier or a dedicated circuit) that is more expensive than AUTOVON could be in the absence of congestion. Here, too, data are insufficient to estimate the level of these costs.

A third cost of congestion, and one for which estimates can be developed, involves the time spent and lost in re-dialing blocked (and pre-empted) calls.

B. ESTIMATING THE COST OF RE-DIALING BLOCKED CALLS

The annual cost of time wasted in re-dialing blocked call-attempts on AUTOVON can be determined in a straightforward manner by multiplying together the following factors:

- Ratio of blocked call-attempts to completed calls
- Average number of completed calls per day
- Number of business days per year
- Average number of minutes spent re-dialing each blocked call
- Wage rate of average caller
- Proportion of re-dialing time which would otherwise have been productive.

In the following discussion, Section 1 explains the assumptions we make with regard to each of these factors, while Section 2 presents estimates of the total annual cost of AUTOVON re-dialing time.

1. ASSUMPTIONS

a. Ratio of Blocked Call-Attempts to Completed Calls

Grade of service on AUTOVON is measured as the average proportion of call attempts which are blocked:

$$G = \frac{b}{b+c} ,$$

where G represents grade of service, b is the number of blocked call-attempts, and c is the number of completed calls. Thus the number of blocked call-attempts can be calculated from information on the grade of service and the average number of completed calls:

$$b = \frac{G}{1-G} \cdot c \ .$$

For this study, $\frac{G}{1-G}$ (i.e., the ratio of blocked call-attempts to completed calls) is calculated as a weighted average of

this same ratio for each AUTOVON calling area, based on the grade of service in each area (see Appendix D), and using each area's share of total access lines as the weights. This ratio amounts to 0.1842 for AUTOVON as a whole, implying an overall grade of service for the AUTOVON backbone between P15 and P16. This method will tend to underestimate the total time wasted re-dialing, since it does not take into account re-dials made necessary by pre-emption of low-precedence calls, or by congestion on access lines. On the other hand, grade of service is measured during busy hours and may overestimate the proportion of blocked call-attempts throughout the business day, causing this method to overestimate blocked call-attempts.

b. Average Number of Completed Calls per Day and Year

DCA estimates an average of 1,100,000 completed AUTOVON calls per business day. Assuming five-day weeks, there are 260 business days and approximately 286,000,000 AUTOVON calls per year.

c. Average Number of Minutes Spent Re-dialing Each Blocked Call-Attempt

Considering time spent dialing and waiting for a busy signal, a blocked call-attempt may take as much as half a minute. If the caller does not immediately re-attempt the call, additional time is wasted. This includes the time lost when other work is resumed and then interupted later. It also includes idle time as some callers simply wait before re-dialing, hoping lines will clear in the meantime. Because the average time lost is not known, we estimate congestion costs for a range of values, including one-half minute, one minute, two minutes, and five minutes per blocked call-attempt.

d. Wage Rate of Average Caller

The rank of the average AUTOVON caller is not known. Officers are more likely to make long-distance calls than enlisted men, but high-ranking officers probably do not waste much time re-dialing calls. They have access to high-precedence telephones, and may ask their subordinates to dial calls for them. This study assumes that the average AUTOVON caller has the rank of Captain, and is paid $1,647.30 per month including basic pay and allowance for quarters. This amounts to 17.2 cents per working minute, assuming working time of 8 hours per day, 5 days per week, and 48 weeks per year.

e. Proportion of Re-dialing Time Which Would Otherwise Have Been Productive

The cost to the government of an officer's wasted time is not necessarily equal to his wage rate. If time wasted redialing blocked call-attempts could have been spent doing something of great importance, the lost opportunity may have cost much more than the officer's wage rate. On the other hand, a caller is not necessarily productive throughout the business day, so that the time spent re-dialing may not interrupt a valuable activity. Accordingly, we estimate the cost of wasted time under a range of assumptions regarding the valuation of time. Assuming that the caller's wage measures the average value of his time when he is productive, we calculate the cost of wasted time for the cases where the caller is productive 100 percent, 50 percent, and 25 percent of the time.

2. ESTIMATES

The cost of time wasted re-dialing blocked call-attempts can be estimated by multiplying together the factors discussed above:

$$\text{Annual Cost of Re-dialing Blocked Calls} = \frac{G}{1-G} \times \text{Number of Calls} \times \text{Number of Days} \times \text{Minutes Per Re-dial}$$

$$\times \text{Captain's Wage Per Minute} \times \text{Proportion of Time Productive}$$

$$C = .1842 \times 1{,}100{,}000 \times 260 \times M \times \$.172 \times P$$

$$C = \$9{,}061{,}166 \cdot M \cdot P \ .$$

Table G-1 reports alternative estimates of the cost of re-dialing blocked call-attempts, using several different values for both M and P.

Clearly, the estimates of costs depend importantly on what assumptions are made regarding M and P. But it is also apparent that millions of dollars are involved. Further, these attempts relate to congestion only on the AUTOVON backbone. Since end-to-end grade of service (considering both the backbone and subscriber access lines) is much higher than backbone grade of service, the total cost of time wasted re-dialing AUTOVON call-attempts is much higher than the estimates reported in Table G-1.

Table G-1. ANNUAL COST OF RE-DIALING BLOCKED CALL-ATTEMPTS[a]

Minutes Wasted Per Blocked Call-Attempt	Proportion of Time Assumed Productive		
	1.00	.50	.25
0.5	$ 4,530,583	$ 2,265,292	$ 1,132,646
1	9,061,166	4,530,583	2,265,292
2	18,122,332	9,061,166	4,530,583
5	45,305,830	22,652,915	11,326,458

[a]These estimates assume the average caller's wage is $0.172 per minute, and consider congestion only on the AUTOVON *backbone*.

Table G-2 presents estimates of the cost of re-dialing blocked call-attempts based on congestion on both the backbone and the destination access lines. These calculations are based on data reported in Appendix D on the percent of calls incomplete by area. This information implies a weighted average (backbone and destination) grade of service of P39, so that the formula for estimating cost is:

$$C = \$31,335,304 \cdot M \cdot P \ .$$

Estimated costs would be even higher if congestion on access lines from call originators to the backbone could be taken into account, but the required information is not available.

Table G-2. ANNUAL COST OF RE-DIALING BLOCKED CALL-ATTEMPTS[a]

Minutes Wasted Per Blocked Call-Attempt	Proportion of Time Assumed Productive		
	1.00	.50	.25
0.5	$ 15,667,652	$ 7,833,826	$ 3,916,913
1	31,335,304	15,667,652	7,833,826
2	62,670,608	31,335,304	15,667,652
5	156,676,520	78,338,260	39,169,130

[a]These estimates assume the average caller's wage is $0.172 per minute, and consider congestion on the AUTOVON *backbone and destination access lines.*

APPENDIX H

FULL-COST ALLOCATION: ASSUMPTIONS & METHODOLOGY

FULL-COST ALLOCATION: ASSUMPTIONS & METHODOLOGY

In this appendix we discuss how the figures presented in Chapter 3, Section C.2 were derived. We first discuss how the costs of different resources were allocated to the various DCS systems. The following costs had to be allocated to different systems in order to determine the cost to government of providing particular DCS services in FY78:

- Cost of owned transmission (excluding satellites). This is an annual cost of procuring, operating and maintaining government-owned transmission media. It is made up of depreciation and O&M cost for owned transmission equipment.
- Cost of satellite transmission. This is depreciation for government-owned satellites and support facilities (including earth terminals).
- Cost of leased circuits.
- Depreciation on owned switches.
- O&M cost of switches (excluding military personnel)
- Overhead. This includes DCA overhead and research and development costs.

After discussing how these costs were allocated to the specific systems, we can then describe how estimates of the impact of full-cost pricing on subscriber charges and on the military departments (MILDEPS) were made.

A. COST OF OWNED TRANSMISSION (EXCLUDING SATELLITES)

There are three kinds of government-owned equipment, excluding satellites: switch equipment, transmission equipment, and equipment to support the transmission media and switches. The DCS Capital Cost Model provides estimates of the

procurement cost in 1978 dollars of DCS equipment on a site-by-site, item-by-item basis. The Capital Cost Model also provides estimates of the cost of buildings and roads needed to house and provide access to the equipment. Also available is the requiring agency for the equipment, which is usually (but not always) the procuring agency. Thus the DCS Capital Cost Model provides the basic data for the allocation of owned equipment.

Because original procurement cost or date of purchase were not available for all the equipment, cost figures used in the DCS Capital Cost Model were based on a variety of sources (in various years). The model has built-in inflators so that the equipment costs can all be stated in terms of one year's dollars. The inflator is based on the Procurement Index published in the US Army Electronics Command Cost Estimating Guide. For our estimates, the costs of the DCS equipment were stated in terms of FY78 dollars. Thus the figures used are closer to replacement costs than original cost. As a result of this process, however, it is possible that the cost of switches may be overestimated since there has been rapid technical change associated with this particular kind of equipment.

Much of the equipment is used to provide service on several systems. Rather than allocate the cost of each and every item to the various systems supported, a much less time-consuming (and less accurate) method of allocating costs was used. The annual cost of owning, operating and maintaining government-owned equipment was allocated to the following systems by geographic area: AUTOVON, AUTODIN, AUTOSEVOCOM, ARPANET, ATSS, access lines for these systems, and dedicated circuits. This allocation process was carried out as follows. First of all, the capital cost of AUTOVON, AUTOSEVOCOM switches, AUTODIN ASCs, and satellite earth terminals were identified and subtracted out of the total capital cost of the DCS. This left

transmission and support costs to be allocated.[1] In order to allocate these remaining capital costs, the costs were first divided into geographic areas: Western Hemisphere (DCA Areas 1, 2 and 9), Europe (DCA Areas 3, 4, 5 and 6) and Pacific (DCA Areas 7 and 8). One-tenth of these amounts was used as the estimated depreciation on the equipment in each area. This assumes straight-line depreciation and a lifetime of ten years for the equipment. A lifetime of ten years for equipment is widely used in the communications industry.

The depreciation on equipment in each geographic area was added to estimated Station Operations (military personnel and O&M) costs for FY78 to estimate the total cost of owning, operating, and maintaining government-owned equipment.[2] Station operations costs represent manpower and other costs of operating and maintaining equipment.

The DCS Operating and Manpower Resources Report II for FY75 was used to estimate the Station Operations costs by geographic area. This report breaks down the O&M and military manpower costs of operating and maintaining DCS equipment by geographic area. The breakdown by geographic area was not available for FY78, so estimates were made. It was assumed that the O&M (or military personnel) costs for each geographic area were the same proportion of the total O&M (or military personnel) cost in FY78 as they were in FY75. Figures for total O&M and military personnel costs for Station Operations for FY78 plus the proportions generated from the FY75 DCS Operating and Manpower Resources Report II gave estimates for the cost of operating and maintaining equipment by geographic area.

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[1]Because it was difficult to distinguish between switch support and transmission support costs by system, all support costs were allocated along with transmission equipment.

[2]This is a slight overestimate since some Station Operations costs go to support the operation of leased equipment such as leased multiplexers.

The sum of depreciation and Station Operation costs for each geographic area then had to be allocated to each DCS system. These costs for the Western Hemisphere were allocated to dedicated circuits, owned AUTODIN and AUTOSEVOCOM access lines, and overhead circuits only, since the other categories of DCS service use leased transmission or satellite transmission.[1] The costs for Europe were allocated to all categories of DCS service in Europe, i.e., AUTOVON backbone-Europe, AUTODIN backbone-Europe, AUTOSEVOCOM backbone-Europe, dedicated circuits-Europe, AUTOVON access lines-Europe, AUTODIN access lines-Europe and AUTOSEVOCOM access lines-Europe. The costs for the Pacific area were allocated to basically all the categories of DCS service in the Pacific.

In order to allocate these costs in each geographic area to a particular DCS system it was assumed that the cost of a specific DCS system in a geographic area is in the same proportion to total cost of all DCS systems in the area as the proportion of the systems weighted circuits to total (weighted) circuits in the geographic area. The circuits were weighted to account for differences in average length and transmission capability. In order to determine weights, the lease cost in CONUS of an average circuit of each type was estimated. It was assumed that these weights would be the same for Europe and the Pacific. The weights used were:

AUTOVON IST	=	3
AUTOVON access lines	=	1
AUTODIN IST	=	7.5
AUTODIN access lines	=	1.33
AUTOSEVOCOM IST	=	2
AUTOSEVOCOM access lines	=	2
ATSS IST	=	7
Overhead	=	2
Dedicated circuits	=	2

The number of circuits of each type in each geographic area were multiplied by the appropriate weights and summed.

[1]While there are probably some AUTOVON access lines that are owned, the majority are leased.

Depreciation and Station Operations costs for a geographic area were then allocated to a system according to the system's proportion of total weighted circuits in the area.

The number of circuits was obtained from the current DCS Circuit and Trunk File. This data base contains information on both leased and owned circuits. The type service (fourth position of the CCSD) and the location of the circuit (from and to destinations) were used to determine the numbers of all different types of circuits in each geographic area as well as between areas (CONUS-Pacific and CONUS-Europe). One problem with using the Circuit and Trunk file is that it includes information on owned and leased circuits which we use to allocate the cost of owned circuits. We are thus assuming the the proportion of owned circuits attributable to a system in an area is the same as the proportion of owned and leased circuits attributable to the system in the area.

B. COST OF SATELLITE TRANSMISSION

The total cost of DCS satellites in FY78 including launch costs was available from the DCS Capital Cost Model. Since military satellites last on average 3.2 years, this figure was used for the expected lifetime of a satellite, as compared with the ten years used for other communications equipment. Earth terminals were assumed to last 10 years. Dividing total satellite costs by 3.2 and adding this to one-tenth of total earth terminal costs gives an annual cost of satellite transmission which was applied to the different DCS systems.

Annual satellite costs were allocated to the circuits they supported. Information on the total number of satellite circuits in each geographic area (and between areas) and the number of satellite circuits used for AUTOVON trunks were available from DCA. It was assumed that the satellite circuits not used for AUTOVON trunks are used for dedicated circuits and not access lines to the switched systems.

C. COST OF LEASED CIRCUITS

In order to allocate the leased transmission cost to different systems, information on the cost of leased equipment and circuits by area (and inter area) and by DCS system was obtained from DCA. These cost figures include the cost of all equipment and circuits leased through the CSIF and thus also include the cost of leased terminal equipment, the cost of other non-DCS equipment, and the O&M cost for AUTOVON switches and AUTODIN ASCs. Thus these figures could not always be used outright.

In order to determine AUTOVON leased transmission costs by area, the total lease cost of the AUTOVON backbone in the area was added to AUTOVON backbone's share of DECCO overhead cost. The O&M cost of the owned switches in the area was subtracted from this total (this O&M cost was included under the Switch O&M category). Thus AUTOVON backbone costs for Europe are equal to the AUTOVON backbone-Europe cost of $1,546,000 plus transoceanic leases for the AUTOVON backbone that are in Europe ($592,000) plus AUTOVON backbone-Europe's share of DECCO costs ($26,000) less the O&M cost of four owned AUTOVON switches in Europe. The O&M cost per switch used for these estimates is the average O&M cost per switch or $1,017,000 per switch. DECCO overhead costs were available by area. These costs were allocated to each system according to the proportion of system cost to total cost in the area.

This same procedure was repeated for the other categories of DCS service with the following exceptions: AUTODIN O&M (excluding military personnel) costs are included by area with the leases. This was done because of the lack of uniformity in the treatment of AUTODIN ASCs. That is, some AUTODIN ASCs are operated and maintained by MILDEPS while some leased ASCs are operated by MILDEPS and maintained by contractor personnel.

Also, the information on dedicated circuits (excluding access lines) involved additional estimation since this category includes much non-DCS lease costs and because not all of the costs were broken down into the different geographic areas. In particular, all transoceanic leases were lumped together instead of being subdivided in CONUS-Caribbean, CONUS-Europe, etc.

In order to determine the lease cost of dedicated circuits, the lease cost of the AUTOVON backbone, the AUTODIN backbone, ATSS, AUTOSEVOCOM, ARPANET, the estimated cost of leased AUTOVON and AUTODIN access lines and the estimated DECCO costs attributable to these leases were subtracted from $240,595,000, the total amount of DCS leases. This last figure was obtained from the DCS budget while other figures were obtained from the CSIF leased equipment information provided by DCA. The amount spent on AUTOVON and AUTODIN access lines excluding terminal equipment was estimated to be the average annual cost of leased AUTODIN and AUTOVON access lines times the number of AUTOVON or AUTODIN access lines. The lease costs were estimated for access lines of average length. As a result of this process, the total lease cost of DCS dedicated circuits (excluding DECCO) was estimated to be $55,046,000 in FY78.

This amount was then allocated to geographic areas (Europe, Pacific, Transoceanic and CONUS) according to the geographic area's share of total VFCT, channel packing and all other CSIF leases. An alternative method which was not used is to allocate the lease costs according to the numbers of dedicated circuits (owned and leased) in each area.

The category of leased dedicated transoceanic circuit cost was allocated to different areas (CONUS-Caribbean, CONUS-Europe, CONUS-Pacific and Pacific) with the aid of information on current transoceanic leases. Information on the $14,699,510 spent on DCS transoceanic leases is available by area. The

estimated FY78 transoceanic lease cost of $13,685,000 was allocated to different areas in the same proportions as current transoceanic lease costs.

Finally, DECCO costs were added back into the cost of dedicated circuits in each area according to the proportion of lease costs in each area.

D. DEPRECIATION ON OWNED SWITCHES

The capital cost of owned switches by area was derived from the DCS Capital Cost Model. The cost of AUTOVON and AUTOSEVOCOM switches and AUTODIN ASCs had originally been subtracted out of the estimated cost of government-owned DCS equipment. The depreciation on this equipment (one-tenth of the capital cost) in each geographic area is the figure used for owned switch cost.

E. O&M COST OF SWITCHES (EXCLUDING MILITARY PERSONNAL)

As described under the section on leased circuits, average O&M costs per government-owned AUTOVON switch were allocated to the areas according to the number of government-owned AUTOVON switches in the area. This was not done for AUTODIN ASCs. In addition, military personnel costs for the O&M of switches was not estimated and applied to the system and area. This is probably a significant amount for AUTODIN ASCs.

F. OVERHEAD AND RESEARCH AND DEVELOPMENT

This category is made up of all other DCS costs--O&M and military personnel costs for Area Operations, Headquarters support by MILDEPs, DCA headquarters support and Research Development Testing & Evaluation (RDT&E). RDT&E was assumed to be research and development costs for future DCS systems. In principle, research and development costs should be treated like physical capital costs. A proportion of the total value of

R&D "stock" should be used to represent FY78 R&D costs. For the purposes of this report, RDT&E in FY78 was used instead of, say, average annual RDT&E expenditures over ten years. RDT&E expenditures have been rising at a rapid rate in recent years. Using RDT&E for FY78 overstates the amount that should be applied to the provision of DCS services in FY78. However, if thus trend continues, it also understates the amount of R&D needed to maintain R&D "stock" (or technical knowledge) necessary for the provision of future DCS services. RDT&E expenditures should also be allocated to the system for which the research expenditure was undertaken. For our estimates, the expenditures that could be identified as relevant to future satellite transmission were allocated to existing satellite circuits. Satellites accounted for $72,251,000 of a total of $97,272,000 RDT&E expenditures in FY78. The rest of the RDT&E expenditures were added into other overhead costs and allocated to the specific systems.

This total of overhead and R&D costs was then allocated to different systems according to each system's proportion of previously allocated costs. The costs previously allocated are all the other costs of providing the service on the system, i.e., the cost of owned and leased equipment and the O&M cost of the switches.

G. COST OF DCS PAID BY MILDEPS

Figures in Table 3-12 and 3-13 are from the DCS Capital Cost Model, the DCS Operating and Manpower Resources Report II and the DCS budget. The amount paid by each MILDEP is the sum of the amount paid in DCS leases (from DCS budget) plus payments made in kind. In-kind payments are the other costs actually incurred by MILDEPS for communications services. The total payment in kind made by each MILDEP is the sum of:

- Depreciation on government-owned equipment (excluding satellites) previously procured by the MILDEP.

- Depreciation for satellite (and launch) cost.
- O&M cost incurred for Station Operations, Engineering and Installation, Area Operations and Headquarters support for each MILDEP.
- Military Personnel cost incurred for Station Operations, Engineering & Installation, Area Operations and Headquarters Support.
- RDT&E cost paid by each MILDEP.

The total amount the MILDEPS would pay under full-cost pricing in the form of AUTOVON charges is based on the number of weighted units for each MILDEP in being in April 1979. AUTODIN full-cost charges are based on estimated weighted units for each MILDEP from the CSIF FY80 budget. In order to estimate the amount each MILDEP would be spending for all other leases under full-cost pricing, the amounts each MILDEP paid in FY78 for the AUTOVON and AUTODIN backbone (from CSIF revenues) were subtracted from the total amount each MILDEP spent for DCS leases. The proportion of the total spent by each MILDEP was used as the estimate of the full cost of other DCS services (excluding AUTOVON and AUTODIN) that each MILDEP would have to pay. This method assumes that all MILDEPS pay on average the same proportion of full cost for all other DCS services. If this is not so, the results will be biased. If, for example, the Air Force uses proportionately more government-owned circuits at zero cost than the other MILDEPS, then the amount the Air Force would have to pay for other DCS services is understated in Table 3-12.